Information Disclosure, Intertemporal Risk Sharing, and Asset Prices*

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Abstract: How much interim information about a financial asset should be disclosed? For example, should a central bank publish bank stress test information, or should a firm issue profit warnings? This paper analyzes the impact of information disclosure on intertemporal risk sharing and asset prices in a competitive economy with short horizon investors. Interim information disclosure triggers interim price movements, but it mitigates price movements at a later date, when the information would otherwise have become public. Disclosure policy can thus be interpreted as a tool to "control" interim asset price movements. As our main theoretical result we show that interim risk sharing (through partial disclosure) can both maximize and *minimize* ex ante market prices. We also discuss which disclosure policy is preferred by different investors' types, and which policy maximizes the sum of investors' utilities. From an empirical perspective, our paper predicts that there is no monotonic relationship between the quality of disclosure and the market value of the firm.

Keywords: Information disclosure, information policy, asset pricing, intertemporal risk sharing, general equilibrium.

JEL-Classification: D92, G14, M41.

1 Introduction

The discussion about the optimal degree of information disclosure is old but still controversial. The recent debate whether the U. S. Federal Reserve Bank and the European Central Bank should announce the results of bank stress tests, has attracted much public and policy attention. The disclosure of information about the state of the banking system and its ability to manage an adverse change in the future macroeconomic environment can be interpreted as a pricing factor that triggers price movements of banks stocks. But this information mitigates price movements at a later date, when the information would otherwise have become public. Consequently, disclosure shifts the timing of price changes and can be interpreted as a mechanism to "control" the timing and magnitude of price changes and intertemporally allocate price risk.[1]

This paper analyzes whether and how the mere announcement to release future interim information *with no impact on the distribution of cash flows* can change today's asset prices in a competitive economy with short horizon investors. We assume that investors need to sell after one period and do not hold the asset until maturity, for example due to short-term consumption plans. This makes short-term price risk relevant.[2] Our paper focuses on the following two interrelated questions. *First*, how does the release of interim information affect interim asset price movements, and thus intertemporal risk sharing among investors? *Second*, how does intertemporal risk sharing among different investors affect the risk premia they demand, and thus ex ante asset prices? The paper discusses which disclosure policy maximizes the ex ante market value of the asset, which policies are preferred by different investors, and which policy maximizes the sum of investors' utilities.

Conventional wisdom may suggest that the announcement of a future announcement is irrelevant for today's market price (see Ross, 1989) or maximizes the market price (see Epstein and Turnbull, 1980; Duffie, Schroder, and Skiadas, 1996, 1997). Gao (2010) states that "most theoretical studies have examined a competitive, pure exchange economy and predicted that disclosure quality monotonically reduces cost of capital" and thus maximizes the market value of the firm.[3] The main result of the present paper shows that intertemporal risk sharing through the release of partial interim information can actually

[1]Another example for the question on how much disclosure is optimal is earnings guidance by public companies. After Congress passed the Safe Harbor law that protected companies from legal liability in performance forecasts, the practice of providing forward-looking information, such as earnings per share guidance, became routine during the late 1990s. The number of firms providing guidance increased from 92 in 1994 to approximately 1200 in 2001. In a survey, 46% of companies that provide earnings guidance say that they do so in order to try to limit stock volatility. See Deloitte Financial Executives Research Foundation, June 2009, "Earnings Guidance: The Current State of the Play," and Thomson Financial, April 2006, "Trends in Earnings Guidance."

[2]Other papers with short horizon traders or myopic investors include Tirole (1982); Spiegel (1998); Allen, Morris, and Shin (2006); Cespa and Vives (2009); Watanabe (2008); Biais, Bossaerts, and Spatt (2010).

[3]We thoroughly relate our paper to the literature in the next section.

minimize ex ante market prices in an economy in which financial markets are competitive and complete. In addition, we characterize how ex ante market prices vary with the precision of interim disclosure and give conditions when partial disclosure minimizes or maximizes market prices. We also derive the disclosure policy that different investor types prefer and the one that maximize the sum of investors' utilities.

In our model, we consider an economy with three dates and three types of agents, E(arly)-investors, M(iddle)-investors, and L(ate)-investors. At date 0, all agents have identical information about the exogenous cash flow distribution of the bank.[4] The bank's cash flow is realized and publicly known at date 2. At date 0, E-investors sell the bank stocks to M-investors for an initial price and consume the proceeds. At date 1, M-investors want to consume and sell their shares to L-investors for an interim price. At date 2, the cash flow is realized and L-investors consume. All types of agents are (equally) risk averse. Asset prices are determined in a system of complete and competitive markets. At any date, there is symmetric information between agents who trade with each other.[5]

At date $\frac{1}{2}$, the central bank conducts a stress test and learns a signal about the final payoff of the stock. In addition, the central bank commits to a disclosure policy at date 0 in the sense that it announces whether and what information it will disclose at date $\frac{1}{2}$. Although E-investors do not face direct price risk, the mere announcement to disclose some information affects the price of the stock at date 0. For a given cash flow process, an interim (date $\frac{1}{2}$) disclosure policy can be used as a mechanism to control interim price movements (i. e., the set of possible interim prices at date 1), and can be interpreted as "fine-tuning" multi-period risk sharing among investors. This affects the risk premia that different cohorts of investors demand, and thus the initial market price of the stock at date 0. If no interim information is released, then M-investors face no risk at all, and L-investors bear the full risk. If vice versa the central bank obtains perfect information and releases all information at date $\frac{1}{2}$ then M-investors bear all the risk (because the interim price at which M-investors can sell the asset fluctuates with the information). Therefore, how M-investors and L-investors share risk affects the initial price at which E-investors can sell the asset to M-investors at date 0.

As a novel result, we show that intertemporal risk sharing through the release of partial interim information can actually *minimize* the initial stock price and the market value of

[4]We discuss disclosure in a banking context as the leading example. More generally, this "bank" could be any firm. Our "central bank" with information about future cash flows would then be the firm's manager.

[5]The main purpose of this paper is to show that even under symmetric information and without moral hazard problems, information disclosure affects asset prices in a non-trivial fashion. With asymmetric information between traders, the market can break down, see Milgrom and Stokey (1982). Adding asymmetric information and analyzing how public information disclosure affect trading in market with asymmetric information is an interesting extension. Dang, Gorton, and Holmstrom (2012) analyze how the provision of public information affects private information acquisition by agents in decentralized markets. They show that the disclosure of noisy information can trigger endogenous adverse selection and reduce trade.

the bank. In the baseline model with two possible final payoffs of the risky asset (high and low), our main parameters are the success probability (probability of the high payoff) and the investors' absolute risk aversion.

The key intuition for understanding whether interim partial disclosure (at date 0.5) minimizes or maximizes the initial price is whether the interim price is closer to the high or the low payoff when there is no disclosure. We use backward induction to determine the initial price. With no disclosure, initial and interim price are identical since investors do not learn anything before trading at date 1.

When does partial disclosure and risk sharing between M- and L-investors minimize the initial price? This case arises if the success probability is relatively high and risk aversion is relatively low. Without interim disclosure, the interim price (and thus also the initial price) is then relatively close to the high payoff. Partial disclosure means that investors obtain a noisy interim signal which can be wrong with positive probability. If the signal suggests that the true state is likely to be high, then there is a relatively large price decline at date 1 and the M-investors bear downside risk. But if the signal turns out to be wrong and the true state is low, the L-investors experience a gain. Because of risk aversion, the potential decline of the interim price that the M-investors face has a higher impact on the initial price than a potential high final payoff. In such a case, partial disclosure causes interim asset price to fluctuate at date 1. Note that, if there is no disclosure, L-investors bear all price risk while M-investors face no risk.

Intuitively, for a disclosure policy to *minimizes* the value at date 0, the sum of the risk premia that M- and L-investors demand is higher than the risk premium that one cohort of investors would demand when it bears all the risk. If the central bank cares about market value of the banking sector at date 0, it chooses a disclosure policy that avoids pronounced upward movements. Also E-investors prefer such a policy.

On the other hand, if the success probability is low or risk aversion is high, the date 1 (and date 0) price is closer to the low final payoff when there is *no* disclosure. Again, L-investors bear all risk. Since the interim price is low, if the true state is high, L-investors make a relatively large gain. Because of high risk aversion L-investors do not value the gains so much. With partial disclosure, the initial price is closer to the true final payoff and the interim price fluctuates. This means M-investors bear some risk. However, the risk premium M-investors require is offset by the reduction in risk premium L-investors require when they bear partial rather than full risk without disclosure. In such a case partial disclosure maximizes the date 0 price and this is what E-investors will lobby for. All these effects are analyzed formally, but also illustrated in a numerical example in Appendix C.

The main analysis is framed in terms of the success probability and risk aversion. However, we can also replace the model parameters by the first three stochastic moments of the final payoff distribution. This permits to derive empirical implications of disclosure policy on ex ante market prices. We show that a high success probability and low risk aversion are equivalent to positive skewness and low variance of the payoff distribution (and vice versa). We show how risk aversion and the skewness of the payoff distribution and disclosure policy affect ex ante market prices. In the Appendix we discuss a case where the payoff distribution is normal and show that partial disclosure minimizes (maximizes) ex ante market price if investors have increasing (decreasing) relative risk aversion.

In the second part of the paper we analyze the preferences of M- and L-investors for disclosure. In a competitive market, investors earn rents for bearing risk. Analogous to the standard demand and supply model, the more risk the investor has to bear, the higher the rents, i. e., the area between demand (marginal willingness to pay) and price curve becomes larger. Although investors are risk averse, they like bearing risk *ex ante* since bearing risk in a competitive financial market means earning higher rents. Consequently, M-investors prefer full disclosure at date $\frac{1}{2}$, while L-investors want the central bank not to disclose any interim information. Different types of investors thus have conflicting interests of information disclosure. We then analyze the optimal disclosure policy if the central bank maximizes the weighted sum of utilities of the three investors' types. We show that partial disclosure can minimize or maximize welfare (i. e., the sum of investors' utilities).

We use a central bank and banking stress test setting as the leading example, but the mechanism, intuitions, and the implications are relevant whenever intertemporal risk sharing among short horizon investors is an issue. Similarly, a central bank or treasury department may decide on how often to release interim macroeconomic information, such as inflation rates, unemployment rates, or GDP growth forecasts. For example, since October 2007 the U. S. Federal Reserve Bank publishes these forecasts every quarter.[6] The release of macroeconomic information typically triggers price movements at the announcement day. Potential price movements affect intertemporal risk sharing between different investor cohorts and thus the market risk premia they demand. Since investors are rational and forward looking, the anticipation of potential interim price movements affect the ex ante market prices.

The rest of the paper is organized as follows. The next section relates this paper to the literature. Section 3 introduces the model. Section 4 analyzes the competitive equilibrium, first of a one-period model, then the two-period model. Section 5 discusses some applications and derives testable hypotheses. Section 6 gives a welfare analysis and discusses the preferred disclosure policy of different cohorts of investors. Section 7 concludes. All proofs are in appendix A. An example with normally distributed payoffs is in section B.

[6] See the Minutes of the Federal Open Market Committee October 30-31, 2007 and the speech of Chairman Ben S. Bernanke at the Cato Institute 25th Annual Monetary Conference, Washington, D. C., November 14, 2007.

2 Relation to the Literature

The literature on information disclosure in financial markets is large and multifaceted. In a seminal paper, Ross (1989) employs the no-arbitrage martingale approach and establishes a *Resolution Irrelevancy Theorem* which states that, in an arbitrage-free economy, a mere change of the timing of the uncertainty resolution cannot change current prices, unless the cash flow distribution is altered.

Epstein and Turnbull (1980) show that in a setting where investors trade and consume in multi-periods, the disclosure of interim information allows for better consumption and trading choices. They show that partial disclosure always maximizes the ex ante market value of the firm. Duffie, Schroder, and Skiadas (1996, 1997) analyze the implications of disclosure of interim information when traders have recursive utilities, and show that noisy disclosure always maximizes the ex ante market value.

In contrast to these papers where interim information disclosure is either irrelevant or always maximizes the value of the firm, the main result of the present paper shows that the disclosure of partial interim information may actually minimize the ex ante market value of a firm despite intertemporal risk sharing. Furthermore, this paper gives conditions when a prescribed disclosure policy of interim information minimizes or maximizes the ex ante market value of the firm.

The main reason for these different results is the following. Ross (1989), Epstein and Turnbull (1980) and Duffie, Schroder, and Skiadas (1996, 1997) assume long-lived investors, while this paper assumes that some investors leave the market so that they only care about prices in some sub-periods of the whole trading setting. This means that investors leaving the market will sell their assets for any positive price. Therefore, the demand side of the market determines asset prices in a competitive equilibrium. But the buyers at date t anticipate that they need to sell at date $t+1$ which determines their willingness to pay at date t. This "recursive" trading structure across investors drives our main result. [7]In Epstein and Turnbull (1980) and Duffie and Manso (2007), all investors have the same preference for interim disclosure policy. In contrast, our paper assumes heterogeneous investors along the time dimension, and is thus able to discuss potential conflicts of interests between investor cohorts regarding the timing of disclosure.

Hirshleifer (1971) argues that information reduces risk averse agents' ability to share risks and thus welfare. Our paper also discusses information revelation and risk sharing but the results are different in three aspects. *First*, the mechanism at work is very different. In our model partial information disclosure implies risk sharing between M-investors and L-investors. This means risk sharing actually can reduce ex ante market price. In Hirshleifer (1971), information reduces risk sharing opportunities while in our paper disclosure improves intertemporal risk sharing opportunities. *Second*,if we define

[7]In Section 4, we discuss the case where only a fraction of investors needs to sell.

welfare as the sum of utilities of all investors, our results are also different. The disclosure policy that maximizes welfare may have some information disclosed. In Hirshleifer (1971) it is always optimal if there is no information disclosure (about agents' types). *Third*, in our model agents know their types (preferences). Since investors have a short horizon, different cohorts of investors have strictly conflicting interests regarding disclosure. There is thus no disclosure policy that Pareto dominates another policy.

There is also a huge accounting and finance literature on financial reporting (for surveys see Verrechia, 2001; Leuz and Wysocki, 2008). A main focus of this literature is that financial reporting may serve as a tool to mitigate and resolve agency problems and adverse selection due to asymmetric information. For example, in Diamond (1985) there is asymmetric information in secondary markets. In Shin (2006), managers and investors have asymmetric information. Also for the special case of central bank communication, there is an immense literature (see, e. g. Blinder, Goodhart, Hildebrand, Lipton, and Wyplosz, 2001), focusing on moral hazard, reputation and commitment issues due to asymmetric information.

In contrast, the present paper abstracts from any type of agency problems and any asymmetric information, but analyzes information disclosure as a tool to control interim price movements and intertemporal risk sharing in an economy with complete and competitive financial markets. Empirical studies on disclosure quality and cost of capital (market value) of the firm do not find a clear pattern (see Leuz and Wysocki, 2008). Our paper predicts that there is no monotonic relationship between the quality of disclosure and the market value of the firm.

The mechanism we identify has implications for the discussion of information disclosure on a firm level (earnings guidance), industry level (bank stress test) and market wide level (unemployment rate, GDP growth, and inflation guidance). We argue that the information about the state of the banking sector which the Fed possess is a pricing factor of banks stocks and represents systemic risk which has a first order effect on asset prices.

3 The Basic Model

The main objective of this paper is to show that in an economy where markets are complete and competitive and agents have symmetric information and there are no moral hazard problems, the disclosure of interim public information can give rise to interesting and novel effects on ex ante asset prices when investors have short trading horizon.[8]

[8] Adding asymmetric information and analyzing how public information disclosure affect trading in markets with asymmetric information is an interesting extension but is beyond the scope of this paper. Dang, Gorton, and Holmstrom (2012) analyze how the provision of public information affects private information acquisition by agents in decentralized markets (see also previous footnote 5).

Utility, Assets, and Endowments of Goods. We consider a competitive economy consisting of three types of agents with unit mass each. The three types of agents are called E-investors (early consumers), M-investors (middle consumers), and L-investors (late consumers). An E-investor has a utility $U_E(c_0, c_1, c_2) = u(c_0)$ and wants to consume at $t = 0$. He is endowed with one unit of a risky asset (e. g., shares of a bank or a firm) that pays off Y units of goods at date 2. The asset yields Y_h units of goods with probability $q \in (0; 1)$, otherwise it yields $Y_l < Y_h$ units of goods. An M-investor has utility $U_M(c_0, c_1, c_2) = u(c_1)$ and owns w units of $t = 0$ goods. An L-investor has utility $U_L(c_0, c_1, c_2) = u(c_2)$ and owns $w > Y_h$ units of $t = 1$ goods. In order to abstract from wealth effects of investors, we assume that all investors have constant absolute risk aversion, $u(c) = -e^{-\rho c}$.

Complete and Competitive Market System. The risky asset is traded in a competitive market. In addition, investors can invest in a risk-free asset at rate r. There are two linearly independent assets and two states, hence the market system is complete. Given the preferences and endowments, E-investors at $t = 0$ sell their asset holding to M-investors for the price P_0 in terms of units of $t = 0$ goods. At $t = 1$, M-investors sells the risky asset to L-investors for the price P_1 in terms of units of $t = 1$ goods.

It is worth noting that in this economy any allocation is Pareto efficient, i. e. it is not possible to make one investor better off without strictly reducing the utility of another investor. Asset prices (only) affect the relative utility of the investors.

The focus of this paper is to analyze how a social planer (central bank) can affect equilibrium prices (and thus the utility of the agents) by interim information disclosure. A central bank that examines all banks has better information about the state of the banking system than any investor in the market. Information about the banking sector is a pricing factor for banks stocks. Therefore, the superior information of the central bank represents systematic risk and is non-diversifiable.

Central Bank and Disclosure Policy. At date 0, the central bank commits to a disclosure policy θ. At date $\frac{1}{2}$ the central bank obtains a perfect signal about the final payoff Y and announces a signal $s \in \{L, H\}$ on the final payoff $Y \in \{Y_l, Y_h\}$. The signal s can be seen as a garbling of the original information (see, e. g., Baglioni and Cherubini, 2007; Weber and Croson, 2004).[9] Formally, $\Pr\{s = h | Y = Y_h\} = (\theta + 1)/2$,

[9] An equivalent modelling strategy is to assume that the central bank's decision is binary. It obtains a noisy signal with precision θ and either announces what it knows or nothing. The employed modelling strategy has the benefit that it highlights how the price at date 0 varies with the signal quality continuously.

Figure 1: Timing of the Model

$t = 0$	The central bank announces a disclosure policy θ and conducts a stress test. E-investors sell the risky asset for the price P_0 to M-investors. E-investors consume P_0 units of goods.
$t = \frac{1}{2}$	The central bank learns the true outcome Y, releases a signal about Y with precision θ.
$t = 1$	M-investors sell the risk asset for a price P_1 to L-investors, and consume $(1+r)(w - P_0) + P_1$.
$t = 2$	The project return is realized. L-investors consume $(1+r)(w - P_1) + Y$ units of goods.

and $\Pr\{s = l|Y = Y_l\} = (\theta + 1)/2$. For $\theta = 1$, there is perfect disclosure, for $\theta = 0$, zero disclosure.[10]

At any dates, there is symmetric information between agents who trade with each other. Trade between M- and L-investors at date 1 will be influenced by the signal; a good signal will lead to a price increase, and the price reaction will be larger if the signal is rather precise. The initial price P_0 cannot depend on the signal s itself, but it may depend on the signal's precision θ. The next section analyzes the function $P_0(\theta)$. As a main result of the paper, $P_0(\theta)$ can exhibit an interior minimum. Figure 1 shows the timing of the model.

In the remainder of the paper we show how the (announcement of a) policy to disclose interim information about final payoff of the risky asset affects date 0 and date 1 asset prices and thus the utility of different investor types and how the optimal policy varies with the weight the central bank is putting on different investor types.

4 Equilibrium Analysis

We first solve the one period model. The case of two periods and an interim signal will then be a straightforward generalization of these first results.

[10] Technically speaking, we can think of disclosure as a computer that draws the information to be release according to an algorithm. The question we address is which algorithm the central bank should set up ex ante.

4.1 The One-Period Case

Consider the market for an asset that pays Y_h with probability q and otherwise Y_l. This is the case that L-Investor is facing when there is no interim disclosure. We omit the time subscript in this section. At a market price P, the expected utility for an investor who buys α units of the risky asset and invests the remaining $w - \alpha\, P_0$ risk-free is

$$\begin{aligned} u(P,\alpha) &= q\, u\big[(1{+}r)(w{-}\alpha\, P) + \alpha\, Y_h\big] + (1{-}q)\, u\big[(1{+}r)(w{-}\alpha\, P) + \alpha\, Y_l\big] \\ &= -\, q\, e^{-\rho\,[(1+r)(w-\alpha\, P)+\alpha\, Y_h]} - (1-q)\, e^{-\rho\,[(1+r)(w-\alpha\, P)+\alpha\, Y_l]}. \end{aligned} \tag{1}$$

In equilibrium, investors must be indifferent to buying an additional marginal share, $\partial u(P,\alpha)/\partial\alpha = 0$. Furthermore, the market must clear; all of the shares must be distributed between investors. Because all investors are identical, a representative investor must hold one share in equilibrium. Consequently, $\partial u(P,\alpha)/\partial\alpha = 0$ for $\alpha = 1$,

$$\begin{aligned} \frac{\partial u(P,\alpha)}{\partial\alpha}\bigg|_{\alpha=1} &= -\, e^{-\rho\,(1+r)\,w}\, \Big[q\, e^{-\rho\,(Y_h-(1+r)\,P)}\, \rho\,(Y_h - (1+r)\,P) \\ &\qquad + (1-q)\, e^{-\rho\,(Y_l-(1+r)\,P)}\, \rho\,(Y_l - (1+r)\,P)\Big] = 0 \implies \\ P &= \frac{1}{1+r}\, \frac{q\, Y_h\, e^{-\rho\, Y_h} + (1-q)\, Y_l\, e^{-\rho\, Y_l}}{q\, e^{-\rho\, Y_h} + (1-q)\, e^{-\rho\, Y_l}} \end{aligned} \tag{2}$$

The market is free of arbitrage; the good event has the risk neutral probability

$$\frac{(1+r)\,P - Y_l}{Y_h - Y_l} = \frac{q\, e^{\rho\, Y_l}}{q\, e^{\rho\, Y_l} + (1-q)\, e^{\rho\, Y_h}}, \tag{3}$$

depending on ρ, Y_h and Y_l. If risk aversion is large, $P = Y_l$; hence, only the bad outcome Y_l is taken into account because $e^{\rho\, Y_h} \gg e^{\rho\, Y_l}$. If risk aversion is low, then $P \approx q\, Y_h + (1-q)\, Y_l$ equals the expected value. Given that (2) is central to our model, let us discuss some elementary properties.

Lemma 1 *Ceteris paribus, (i) a higher interest rate r decreases the price P, (ii) a higher success probability q increases the price, (iii) a higher risk aversion ρ decreases the price, (iv) a higher low yield Y_l increases the price, (v) a higher high yield Y_h increases the price to some maximum.*

The first four properties are not surprising. However, the last point states that the market price P does not increase monotonically with the good-state return Y_h. In other words, the asset market does not honor large potential increases in value.[11] The reason is

[11] This property is not a consequence of exponential utility; it holds for more general types of utility functions, such as CRRA functions and logarithmic functions. We show this at the end of the proof of Lemma 1. Of course, it cannot hold for risk neutrality.

that the *marginal* expected utility of a share, not its actual expected utility, determines the market price of an asset. The marginal utility from a payment Y_h decreases as Y_h increases. Consequently, the market price may even decrease as Y_h increases. Let us thus stress that the benefit to initial investors from large potential price increases is limited. This property will later help explain why interim information disclosure and interim risk sharing can minimize the current market price.

The interest rate r appears only as a discount factor $1/(1+r)$; hence, it cannot influence the optimal disclosure policy. As a result, we can set $r = 0$ without loss of generality in the following.

4.2 The Two-Periods Case with an Interim Signal

We now solve the full model using backward induction. If there is information disclosure at date 0.5, using equation (2) the date 1 price depends on the signal s, and is given as follows. If the signal is good, then

$$P_{1h} = \frac{\Pr\{Y_h|s=h\} \cdot Y_h \cdot e^{-\rho Y_h} + \Pr\{Y_l|s=h\} \cdot Y_l \cdot e^{-\rho Y_l}}{\Pr\{Y_h|s=h\} \cdot e^{-\rho Y_h} + \Pr\{Y_l|s=h\} \cdot e^{-\rho Y_l}}. \tag{4}$$

If the signal is bad, then

$$P_{1l} = \frac{\Pr\{Y_h|s=l\} \cdot Y_h \cdot e^{-\rho Y_h} + \Pr\{Y_l|s=l\} \cdot Y_l \cdot e^{-\rho Y_l}}{\Pr\{Y_h|s=l\} \cdot e^{-\rho Y_h} + \Pr\{Y_l|s=l\} \cdot e^{-\rho Y_l}}. \tag{5}$$

where

$$\begin{aligned}
\Pr\{Y=Y_h|s=h\} &= \frac{\Pr\{s=h|Y=Y_h\} \cdot \Pr\{Y=Y_h\}}{\Pr\{s=h\}} = q\,\frac{1+\theta}{1+\theta\,(2\,q-1)}, \\
\Pr\{Y=Y_h|s=l\} &= \frac{\Pr\{s=l|Y=Y_h\} \cdot \Pr\{Y=Y_h\}}{\Pr\{s=l\}} = q\,\frac{1-\theta}{1-\theta\,(2\,q-1)},
\end{aligned} \tag{6}$$

and furthermore $\Pr\{Y = Y_l|s = h\} = 1 - \Pr\{Y = Y_h|s = h\}$ and $\Pr\{Y = Y_l|s = l\} = 1 - \Pr\{Y = Y_h|s = l\}$. Note that, for $\theta = 0$, we have $\Pr\{Y = Y_h|s = h\} = q$, the signal contains no information. For $\theta = 1$, we get $\Pr\{Y = Y_h|s = h\} = 1$. As a consequence, depending on the signal, the date 1 price of the asset fluctuates. After positive information, the price jumps up. These potential price movements determine the risk that M-investors must bear.

Analogously, using equation (2) we can determine the date 0 price. We use Bayes' rule to determine the probability $\Pr\{s = h\}$ that a good interim signal occurs. The initial price P_0 will depend on the expected intermediate prices P_h and P_l.

The ex ante probability that a positive signal $s = h$ occurs is

$$\Pr\{s=h\} = q\,\Pr\{s=h|Y=Y_h\} + (1-q)\,\Pr\{s=h|Y=Y_l\} = \frac{1+(2\,q-1)\,\theta}{2}.$$

Using (2), we find that the price at date $t = 0$ will be

$$P_0 = \frac{\Pr\{s = h\}\, P_h\, e^{-\rho\, P_h} + \Pr\{s = l\}\, P_l\; e^{-\rho\, P_l}}{\Pr\{s = h\}\, e^{-\rho\, P_h} + \Pr\{s = l\}\, e^{-\rho\, P_l}}. \tag{7}$$

where $\Pr\{s = h\}$, $\Pr\{s = l\}$, P_l and P_h are given above. Before discussing the general properties of the date 0 price in this model, we first consider some numerical examples.

Suppose $Y_h = 1$, $Y_l = 0$, $q = 50\%$, $\rho = 2$, and $\theta = 25\%$. This is the second example in Table 1 in Appendix C. For these parameters, we obtain $\Pr\{s = h\} = 50\%$, $\Pr\{Y = Y_h|s = h\} = 62.5\%$, and $\Pr\{Y = Y_h|s = l\} = 37.5\%$. Using backward induction, one can calculate the price after a good signal as $P_h = 0.184$, the price after a bad signal as $P_l = 0.075$, and the initial price as $P_0 = 0.124$. According to (3), risk-neutral probabilities are 44.6% for a good signal, 18.4% for a good outcome after a good signal, and 7.5% for a good outcome after a bad signal. Due to the high degree of risk aversion, risk-neutral probabilities differ substantially from actual probabilities. Now there is an alternative way to calculate the initial price, $(44.6\% \cdot 18.4\% + (1 - 44.6\%) \cdot 7.5\%) \cdot 1 = 0.124 = P_0$.

What is the degree of disclosure θ that maximizes the price P_0? Unlike Ross (1989), we do not find a general resolution irrelevance theorem; however, we find resolution irrelevance at the extreme points $\theta = 0$ (no disclosure) and $\theta = 1$ (perfect disclosure).

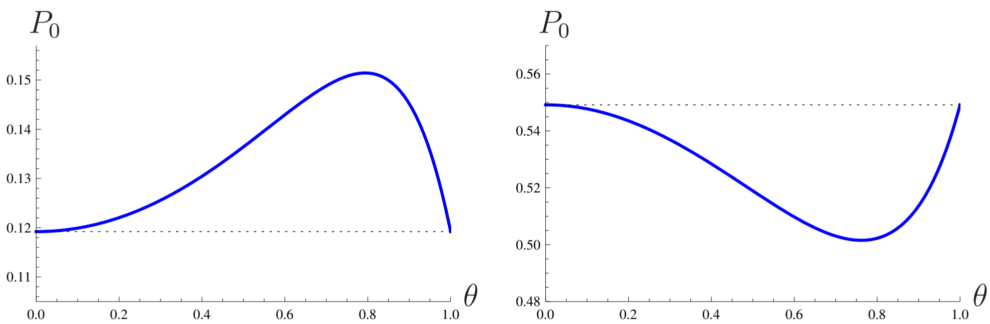
Lemma 2 (Resolution Irrelevance at the Extremes) *The market value is the same for zero disclosure and for full disclosure, $P_0(\theta = 0) = P_0(\theta = 1)$.*

The intuition for this lemma is straightforward. If the interim signal is perfect, $\theta = 1$, L(ate)-investors will perfectly know the final outcome before they trade. Consequently, date-1 prices will be either $P_h = Y_h$ or $P_l = Y_l$. The probability of a high signal will be q, and the probability of a bad signal will be $1 - q$. Hence, all risk is borne by the M(iddle)-investors. If the interim signal carries no information, $\theta = 0$, then nothing is learned by M-investors, and there is no price movement, i. e., $P_h = P_l = P_0$. Hence, all risk in terms of asset payoff is borne by L-investors. In both cases, one cohort bears the complete risk, while the other uses the shares as a risk-free investment. "Swapping" cohorts does not change the initial price P_0.[12]

Full disclosure and no disclosure yield the same initial price, P_0. But what happens in between? In Figure 2, the function $P_0(\theta)$ is plotted for two different parameter constellations. In the left graphic, parameters are $Y_h = 1$, $Y_l = 0$, $\rho = 2$, $q = 50\%$. In the right graphic, parameters are the same, only $q = 90\%$. These examples suggest several results. *First*, there is no resolution irrelevancy in general. Both graphics document the

[12]This result depends on the assumption that risk aversion and the number of investors are the same in both cohorts. Otherwise, the price would be higher if risk were shifted to the less risk-averse cohort or to the larger cohort.

Figure 2: Effect of Disclosure Policy θ on the Initial Price P_0



fact that $P_0(\theta = 0) = P_0(\theta = 1)$, but in between, the functions are non-constant. *Second*, there can be an interior maximum (left graphic). The market value maximizing policy is to release some information to the market, but only *vague* information. *Third*, the novel result is that it is possible that partial information reduces market value (right graphic). In this case, the market value maximizing policy is to choose no disclosure ($\theta = 0$) or full disclosure ($\theta = 1$) but it avoids the release of any imprecise interim information.

Note, if the central bank obtains a noisy interim signal which we formalize below, then only the no disclosure policy maximizes the date-0 price and the market value of the firm or bank.

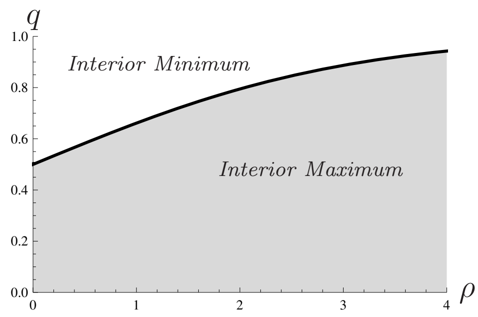
Now we provide the conditions under which partial disclosure minimize market value, or equivalently when $\theta = 0$ or $\theta = 1$ (zero or full disclosure) maximizes the market value. But let us simplify the problem by setting $Y_l \equiv 0$ and $Y_h \equiv 1$. The following lemma shows that we do not lose any generality.

Lemma 3 (Symmetry Results) *The following two statements hold true,*

$$P_0(Y_h, Y_l, \rho, q, \theta) = P_0(Y_h - Y_l, 0, \rho, q, \theta) + Y_l \quad \textit{and}$$
$$P_0(Y_h, 0, \rho, q, \theta) = Y_h \, P_0(1, 0, \rho \, Y_h, q, \theta).$$

The first statement tells us that if we increase both Y_h and Y_l by the same amount, the market price increases by exactly this amount. Consequently, we can consider $P_0(\Delta Y, 0, \rho, q, \theta)$ instead of $P_0(Y_h, Y_l, \rho, q, \theta)$ without loss of generality, where $\Delta Y = Y_h - Y_l$. The second statement tells us that multiplying Y_h by some constant has the same effect on market prices as multiplying ρ by the same constant *and* multiplying the price by the same constant. Consequently, we can consider $P_0(1, 0, \rho \, \Delta Y, q, \theta)$ instead of $P_0(\Delta Y, 0, \rho, q, \theta)$. Without loss of generality, we can even set $\Delta Y \equiv 1$, bearing in mind that an increase in variation ΔY has the same effect as an increase in risk aversion ρ. Now, only two exogenous parameters are left in the model, risk aversion ρ and and success probability q. The following proposition states their influence on the optimal disclosure policy.

Figure 3: Market Value Maximizing Policy



Parameters are $Y_h = 1$ and $Y_l = 0$. However, because of Lemma 3, ρ and q represent the complete parameter space without loss of generality. The black curve gives condition (8), so that above this curve, the function $P_0(\theta)$ has an interior minimum; below the curve, $P_0(\theta)$ has an interior maximum.

Proposition 1 (Market Value Maximizing Policy) *The function $P_0(\theta)$ has an interior maximum θ^* if*

$$q < \frac{e^\rho \left(e^\rho - \rho - 1\right)}{\left(e^\rho - 1\right)^2}. \tag{8}$$

Because the function $P_0(\theta)$ is not constant, if it does not have an inner maximum, it must exhibit an inner *minimum.* Hence, sharing financial risk between cohorts can increase the market valuation P_0, but it does not have to. Intertemporal risk sharing is thus fundamentally different from static risk sharing. The aggregate risk premium may be minimized if all risk is shifted to one cohort.

The proposition is illustrated in Figure 3. For large q or for low ρ, we end up in the white region where zero (or full) disclosure maximizes market value. For small q or for high ρ, noisy disclosure maximizes market value (gray region). The black curve marks critical parameter combinations, as defined by (8). Let us give some idea why there may be an interior optimum in the first place and how q and ρ influence this property.

If q is low or ρ is high, the initial price P_0 lies relatively low in the range $[Y_l; Y_h]$. From the fifth point of Lemma 1, we know that E-investors benefit from value increases for M-investors only up to a point. Therefore, a P_0-maximizing disclosure policy is to avoid large upward price jumps. This can be accomplished by partial disclosure, $0 < \theta < 1$. As a result, risk is distributed more evenly between cohorts.

The intuition for the possibility of an interior minimum when q is high and ρ is low, is the following. Without interim disclosure, the date-1 price (and thus date-0 price) is close to the final payoff Y_h. Partial disclosure means that investors obtain a noisy interim signal which is wrong with positive probability. If the signal suggests that Y_l is likely to be the final payoff, then there is a relatively large price decline at date 1 such that the

M-investors bear downside risk. But if the signal turns out to be wrong and the true state is $Y-h$, the L-investors experience a gain. Because of risk aversion, the potential price decline that the M-investors face at date 1 has a higher impact on the date 0 price than a potential price increase (or high payoff) that L-Investors might experience at date 2. In such a case, partial disclosure causes prices to fluctuate at date 1. Note that, if there is no disclosure, L-investors bear all price risk while M-Investors face no risk.

Intuitively, for a disclosure policy to *minimizes* the value at $t=0$, the sum of the risk premia that M- and L-investors demand is higher than the risk premium that one cohort of investors would demand when it bears all the risk. This argument explains why the function $P_0(\theta)$ has an interior minimum for high q and low ρ.

On the other hand, if q is low or ρ is high, the date 1 (and date 0) price is closer to the final payoff Y_l when there is no disclosure. Again, L-investors bear all the risk. Since the date 1 price is low, if the true state is Y_h, L-investors make a relatively large gain. Because of high risk aversion L-investors do not value the gains so much. With partial disclosure, the date 1 price is closer to the true final payoff and the date 1 price fluctuates. This means M-Investors bear some risk. However, the risk premium M-investors require is offset by the reduction in risk premium L-investors require when they bear partial rather than full risk without disclosure.

We have assumed that the central bank can choose θ within the interval $[0;1]$. In reality, there may be reasons why this interval is trimmed. *First*, information may leak out of the firm at the interim date. Investors will then aggregate this information and the disclosed signal precision θ to a new signal. This signal will then have some minimum precision $\theta_{\min}$, equal to the quality of the leaking information. If the price function has an interior minimum (see Figure 3), the maximum is reached for full disclosure, $\theta^*=1$. *Second*, the final outcome Y may not be predictable with certainty, entailing a maximum precision $\theta_{\max}$. The precision can be reduced by additional garbling, but it cannot be increased. Then if the price function has an interior minimum, the maximum is reached for zero disclosure, $\theta^*=0$. Our model implies that, if the future becomes less predictable and the maximum precision $\theta_{\max}$ is reduced, and the central bank cares about current price stability, it switches to zero disclosure (instead of just reducing disclosure).

Note one interesting re-interpretation of the result. We have assumed that the mass of investors is 1. An interesting question is: how does the disclosure policy change if ownership is concentrated? Assume for example that just a small fraction of investors can hold the asset. Then, each investor must hold a larger share of the firm. It can be shown that formally, this is equivalent to a higher gap between Y_h and Y_l, which is again equivalent to a higher degree of risk aversion ρ. As a consequence, Proposition 1 implies that partial disclosure is optimal for firms with high ownership concentration.

5 Applications and Hypotheses

In this section, we apply the model to a number of questions and derive testable hypotheses. Some applications are immediate consequences of the model; for others, we have to modify the assumptions.

5.1 The Shape of the Distribution

We can fully characterize a two point distribution by knowing its first three stochastic moments. Loosely, speaking the skewness of a two point distribution captures whether Y_l or Y_h is closer to the mean. By expressing the underlying parameters of the model (i. e., Y_l, Y_h, q, ρ) in terms of mean, variance and skewness of the payoff distribution, we obtain empirical predictions of disclosure policy on the market value of the firm.

We have seen that the optimal disclosure policy depends on the success probability q and risk aversion ρ, where ρ is short for $\rho\,(Y_h - Y_l)$ because we have set $Y_h = 1$ and $Y_l = 0$ without loss of generality. Both parameters q and ρ are connected to the shape of the distribution. For easier interpretation, let us thus rewrite the results in terms of *stochastic moments*. First, the first statement of Lemma 3 states that increasing both Y_h and Y_l by the same amount c only shifts the complete function $P_0(\theta)$ upwards by c. The shape of the function does not change; hence, the optimal θ remains constant. Consequently, the optimal disclosure policy does not depend on the mean of the yield distribution.

Second, ρ appears only in the factor $\rho\,(Y_h - Y_l)$. Instead of setting $Y_h = 1$ and $Y_l = 0$, let us set $\rho = 1$ and $Y_l = 0$ without loss of generality. We are left with the two parameters Y_h and q. Now, the second stochastic moment σ and the third moment ν of the distribution are functions of Y_h and q,

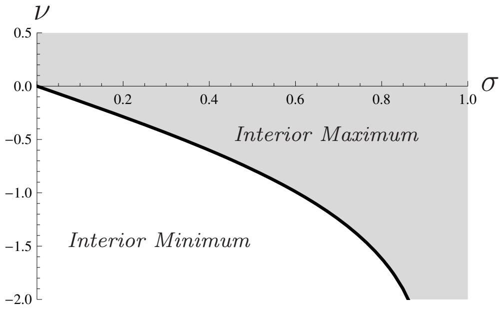
$$\begin{aligned}
\mu &= q\,Y_h + (1-q)\,Y_0 = q\,Y_h, \\
\sigma &= \sqrt{q\,(Y_h-\mu)^2 + (1-q)\,\mu^2}, \\
\nu &= \frac{q\,(Y_h-\mu)^3 - (1-q)\,\mu^3}{\sigma^{3/2}}.
\end{aligned} \tag{9}$$

Conversely, one can write q and Y_h as implicit functions of the standard deviation σ and skewness ν,

$$\begin{aligned}
Y_h &= \sigma\,\sqrt{4+\nu^2}, \\
q &= \frac{1}{2} - \frac{\nu}{2\,\sqrt{4+\nu^2}}.
\end{aligned} \tag{10}$$

Figure 4 shows for which combinations of standard deviation σ and skewness ν the price function has an interior maximum. We obtain the following remark.

Figure 4: Market Value Maximizing Policy



Parameters are $\rho = 1$ and $Y_l = 0$. The figure shows the optimal disclosure policy, depending on standard deviation σ and skewness ν. The figure illustrates Remark 1: the price function has an interior maximum for high standard deviation σ and high skewness ν.

Remark 1 *The mean of the payoff distribution does not influence the market value maximizing disclosure policy. The function $P_0(\theta)$ has an interior maximum θ^* for high standard deviation σ and high skewness ν.*

Note that σ and ν are stochastic moments of the payoff Y, not of the probability distribution of prices P_1 (which is endogenous). Arguably, both risk and skewness are higher in innovative industrial sectors. Projects are likely to fail, but if they do not fail, they can deliver high returns. The distribution is typically skewed to the right (positive skewness). Consequently, the above remark implies a high level of disclosure. For more traditional industries, the risk is relatively small and the distribution is skewed more to the left. The remark thus predicts less disclosure at all for traditional industries.

5.2 Market Liquidity

In the baseline model, all M-investors have to sell at date 1. Consequently, the complete market volume is turned over at date 1. In reality, assets have different degrees of liquidity: for some, the turnover at each trading date may be low. One may want to ask the question whether an asset's liquidity affects the optimal disclosure policy. Let us assume that only a fraction of M-investors needs to sell at date 1, thus reducing the turnover (liquidity). There are a couple of consequences. Because some investors hold the asset for both periods, the importance of intertemporal risk sharing will decrease, and the impact of disclosure levels on share prices will decline. The market value maximizing *level* of disclosure may also change. We show that the condition under which there is an inner optimum for disclosure does not change.

Let us now assume that, at date 1, only a fraction $\lambda \leq 1$ of M-investors must leave the market (potentially due to a stochastic liquidity shock, like in Diamond and Dybvig

(1983)), but another mass λ enters the market. Hence, the aggregate mass of investors is 1 at each date. Now λ is a measure for market turnover, or liquidity. For $\lambda = 0$, there is no interim trading, and disclosure policy is irrelevant. For $\lambda = 1$, the complete volume is traded at $t = 1$, and we have our original model.

Prices are determined only by future payoff expectations. They are independent of whether investors have held the asset in the preceding period or not. Consequently, interim prices at date $t = 1$ are independent of liquidity λ. P_h and P_l are not influenced by whether an asset has been held or traded, hence P_h and P_l are independent of λ. However, the initial price P_0 will be influenced by λ. When making buying decisions at $t = 0$, M-investors take into account that they will hold the asset until $t = 2$ with probability $1-\lambda$, and get payoffs of Y_h and Y_l with the according probabilities, or need to sell the asset at $t = 1$ with probability λ, and get payoffs of P_h and P_l with the according probabilities. The expected utility of buying α units of the asset at $t = 0$ is

$$\begin{aligned} u(P_0, \alpha) = \lambda \Big(&\Pr\{s = h\}\, u\big[w + \alpha\,(P_h - P_0)\big] \\ &+ (1 - \Pr\{s = h\})\, u\big[w + \alpha\,(P_l - P_0)\big]\Big) \\ &+ (1-\lambda)\Big(q\, u\big[w + \alpha\,(Y_h - P_0)\big] + (1-q)\, u\big[w + \alpha\,(Y_l - P_0)\big]\Big). \end{aligned} \tag{11}$$

In the competitive market equilibrium, $\partial u(P_0, \alpha)/\partial\alpha = 0$ must hold, and the market must clear, $\alpha = 1$. This again yields an implicit function $P_0(\theta)$, which may exhibit an interior maximum or minimum. We have already discussed the extreme case of a maximally liquid market, $\lambda = 1$. For the following remark, liquidity λ may take any value; we show that Proposition 1 holds for any λ.

Numerical simulations show two more properties. First, the impact of disclosure is smaller for larger levels of liquidity λ. Second, the optimal degree of disclosure θ^* depends positively on liquidity λ.

Remark 2 *The question whether partial disclosure maximizes market value is independent of the degree liquidity λ.*

5.3 Additional Portfolio Risk

Arguably, investors may face other financial risk from outside the firm. A typical investor holds more than one asset, hence the shares will be part of a larger portfolio. Then, one may ask whether the conditions under which partial disclosure or full disclosure maximize the market value of the asset are unchanged. Potentially, if there is more risk, the optimal allocation of risk between investors look different. Assume that agents own some other asset that yields a risky X. Assume furthermore that X is stochastically independent from $Y \in \{Y_l, Y_h\}$,[13] and follows the distribution $F(X)$ with density $f(X)$. This X could, for example, stand for the "everything else" that an agent owns.

Remark 3 *In the presence of additional risk, the function $P_0(\theta)$ has an interior maximum under the same conditions as in the absence of further risk.*

This remark is important from a theoretical perspective. Even if an asset contributes only a small fraction of an average investor's portfolio, disclosure decisions influence its market price. Empirical studies on disclosure quality and cost of capital (market value) of the firm do not find a clear pattern (see Leuz and Wysocki, 2008). Our paper predicts that there is no monotonic relationship between the quality of disclosure and the market value of the firm. If interim information is noisy and all firms are subject to the same disclosure standards (e. g. about fiscal year earnings), then this tends to decrease the cost of capital (increase market value) of firms with a positively skewed cash flow distribution (high tech firm) while it tends to increase the costs of firms with more negatively skewed distributions.

6 The Investors' Interests and Welfare

So far we have focused on a disclosure policy that maximizes P_0, which is equivalent to maximizing the utility of E-investors. However, M- and L-investors will not be indifferent with respect to the allocation of risk over time. In this section, we first argue that the first-best allocation cannot be obtained with information disclosure as the only tool. We then analyze the interests of M- and L-investors, and conclude with a discussion of welfare.

Consider at date $t = \frac{1}{2}$ the case that the central bank has positive information. The case with negative information is analogous. E-investors have already quitted the game. The aggregate utility of M- and L-investors is

$$u\big[(w - P_0) + P_h\big] + u\big[(w - P_h) + Y_h\big] \tag{12}$$

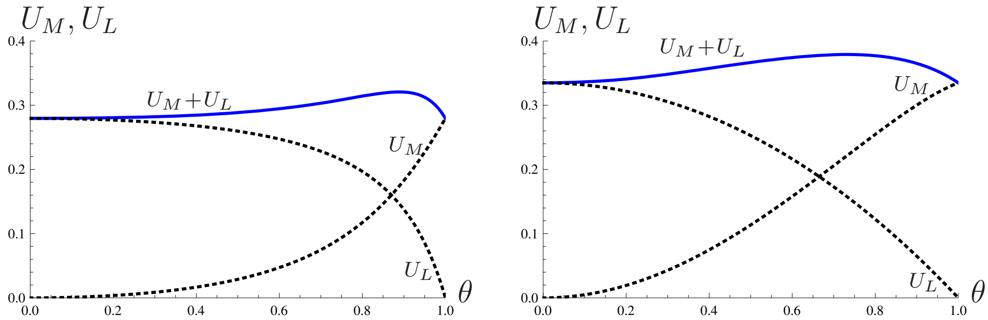
The first-order condition yields

$$P_h^* = \frac{P_0 + Y_h}{2}. \tag{13}$$

This price leads to a transfer between M- and L-investors that aligns their marginal utilities. In particular, at this point, it is non-stochastic. If the central bank would want to reach this price P_h^* with information policy only, it would have to issue a non-stochastic signal. Investors could thus perfectly infer the state h from the signal. But

[13] If X and Y were correlated, then the signal s would contain information not only about Y, but also about X.

Figure 5: M- and L-Investors' Expected Utility



Like in Figure 2, $q = 50\%$ in the left picture, and $q = 90\%$ in the right.

then, the market clearing condition would yield the equilibrium price $P_h = Y_h$. This proves that disclosure policy as the only policy tool cannot implement the first-best.

We now discuss the interests of M- and L-investors. They are indifferent with respect to buying one more marginal share at the given price, but this does not imply that they do not earn any rents. If information is perfect and the final payoff Y is known, an investor's demand function would be flat, hence his rent would be zero. When stock prices fluctuate, demand for shares is elastic, and thus rents will be positive. The higher the risk for a cohort of investors, the higher the rents that this cohort will earn. As a consequence, from an *ex ante* perspective, each cohort will want to bear as much risk as possible. For example, M-investors prefer full disclosure ($\theta = 1$). In that case, they bear a large interim price risk. The risky asset is all but a perfect substitute for the risk-free investment. Hence, in that case, M-investors earn large rents. Analogously, L-investors prefer $\theta = 0$. This is illustrated in Figure 5. Once M-investors have bought the asset, they are already compensated for the risk. They now prefer the asset to be safe, which is equivalent to zero disclosure.

Lemma 4 (Divergence of Interests) *From an ex ante perspective, M-investors prefer $\theta = 1$ (full disclosure); L-investors prefer $\theta = 0$ (zero disclosure).*

Investors like risk *ex ante* because it enables them to pay a low price for the asset. Consequently, their attitude changes as soon as they have bought the issue: M-investors will prefer not to have any information revealed while they own the shares. The same holds true for L-investors. The lemma suggests that, if disclosure standards were determined in a political process, the result would heavily be influenced by the timing of the decision (and by the proportion between cohorts of investors). Each cohort would lobby towards vague disclosure once they held shares; beforehand, they would argue they want to have access to information as soon as it is available.

Figure 5 shows the expected utilities of M- and L-investors as dotted lines for two numerical examples that illustrate Lemma 4: U_M increases with θ, whereas U_L decreases. It also shows the sum of utilities, $U_M + U_L$. For both parameter constellations, this sum has an inner maximum $\hat{\theta}$. The following proposition shows that this is a general property. It (seemingly) contains a paradox. Although M- and L-investors, in the aggregate, always prefer to smooth risk between generations (Proposition 2), this is not necessarily reflected in the asset price P_0 (Proposition 1).

Proposition 2 *The sum of expected utilities $U_M + U_L$ is always maximized with partial disclosure, $\hat{\theta} \in (0; 1)$*

The reason why there is always an interior maximum at an interior $\hat{\theta}$ differs slightly from the explanation for an interior maximum of $P_0(\theta)$. A single investor cohort's ex ante utility generally increases with the amount of risk it takes. However, due to risk aversion, the marginal utility with respect to taking more risk decreases and can even become negative. This implies that by sharing risk between the M- and L-investors, the aggregate rent of investors is maximized. A formal proof can be found in the appendix.

Welfare. Proposition 1 considers the interests of E-investors (to maximize the initial price P_0), Proposition 2 considers the aggregate interests of M- and L-investors. What about aggregate welfare (defined as the sum of the utilities of all three cohorts of agents, $W = U_E + U_M + U_L$)? We want to argue that aggregate welfare as a function of the disclosure policy, $W(\theta)$, can exhibit an interior maximum, but also a minimum. One component of welfare, $U_M + U_L$, always has an interior maximum. The other component, U_E, depends on the price $P_0(\theta)$, which can have a minimum or maximum. If it has an inner maximum, for example because risk aversion is high or the success probability is low (Proposition 1), then the case is closed: a partial disclosure policy must maximize welfare.

If $P_0(\theta)$ has an inner minimum, however, then the behavior of aggregate welfare depends on the relative size of the two effects. Because investors are risk averse, and their utility functions become flatter for large wealth levels, if the M- and L-investors' endowment w is large, the absolute level of their utility hardly moves for changes in θ. The impact of $P_0(\theta)$ then dominates that of U_M and U_L, and the welfare function is hump-shaped. This simple consideration shows that partial disclosure may minimize not only $P_0(\theta)$, but also aggregate welfare.

7 Conclusion

Introducing liquidity concerns into a disclosure model with risk averse and short horizon investors in an economy with complete and competitive financial markets, we derive a rich set of implications for asset prices, even in the complete absence of asymmetric information, moral hazard, and trading frictions. In particular, we show that partial disclosure of interim information and interim risk sharing can minimize the ex ante market price of a risky asset. We show that there is no monotonic relationship between the quality of disclosure and the market value of a firm.

The novel result that interim disclosure can minimize or maximize ex ante market prices in an economy with short horizon investors is relatively intuitive. If the priors about fundamentals (payoff distribution and risk aversion) give rise to high ex ante market prices when there is no disclosure, then disclosing partial interim information minimizes ex ante market prices. Since information is noisy, investors obtain information that is wrong with positive probability. If the signal suggests a low final payoff this causes a relatively large price decline and investors selling at that date face large downside risk. But if the final payoff turns out to be high late investors make a relatively large gain. Disclosure causes interim prices to fluctuate. Because of risk aversion the first effect can dominate the second one. Therefore, disclosing noisy interim information can minimize ex ante market prices.

On the higher hand if investors' prior and risk aversion give rise to low ex ante market prices when there is no disclosure, then partial interim information disclosure maximizes market prices. Since investors are risk-averse, the market's appreciation for large upward value increases of an asset is limited. Hence caring about current market prices, one should design the disclosure policy to avoid large interim upward jumps.

In terms of stochastic moments of the payoff distribution we show that if the distribution exhibits negative (positive) skewness, i. e., there is a low probability of a large downside risk (high upside gains), partial disclosure minimizes (maximizes) ex ante market prices. In the Appendix we show that these results also hold when the payoff distribution is normally distributed. If agents have constant CARA, the ex ante market price is independent of interim disclosure. But if agents have decreasing (increasing) absolute risk aversion, then partial disclosure maximizes (minimizes) ex ante market prices.

This paper identifies a new mechanism of how the disclosure of interim information affects ex ante asset prices through intertemporal risk sharing. The results have implications for the discussion of information disclosure on a firm level (earnings guidance), industry level (bank stress test) as well as market wide level (unemployment rate, GDP growth, and inflation guidance). Some of the information represents systematic risk and has a first order effect.

As a second main result, this paper shows that there is disagreement about the optimal disclosure policy among different investor types. Investors who enter the market in subsequent periods prefer different disclosure policy than the one that maximizes ex ante market prices. There is conflict of interest between different types of stock holders. Another important class of stakeholders in a bank is depositors. Dang, Gorton, Holmstrom, and Ordonez (2013) show that depositors have a strict preference that information is kept secret.

In the light of the recent financial crisis, the academic and policy debate about information disclosure and the role of transparency is likely to remain controversial, especially in financial institutions. Our paper adds the aspects of liquidity concerns and intertemporal risk sharing among short-term stock holders to the debate by delivering some new insights.

A Appendix

Proof of Lemma 1: According to (2), the equilibrium price is

$$P = \frac{1}{1+r}\,\frac{q\,Y_h\,e^{-\rho\,Y_h} + (1-q)\,Y_l\,e^{-\rho\,Y_l}}{q\,e^{-\rho\,Y_h} + (1-q)\,e^{-\rho\,Y_l}}.$$

Taking derivatives, we obtain

$$\begin{aligned}
\frac{dP}{dq} &= \frac{1}{1+r}\,e^{\rho\,(Y_h+Y_l)}\,\frac{(Y_h-Y_l)}{(q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h})^2} > 0,\\
\frac{dP}{d\rho} &= -\frac{1}{1+r}\,q\,(1-q)\,e^{\rho\,(Y_h+Y_l)}\,\frac{(Y_h-Y_l)^2}{(q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h})^2} < 0,\\
\frac{dP}{dY_l} &= \frac{1}{1+r}\,(1-q)\,e^{\rho\,Y_h}\,\frac{q\,e^{\rho\,Y_l}\,(1+\rho\,(Y_h-Y_l)) + (1-q)\,e^{\rho\,Y_h}}{(q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h})^2} > 0,\\
\frac{dP}{dY_h} &= \frac{1}{1+r}\,q\,e^{\rho\,Y_l}\,\frac{q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h}\,\,(1-\rho\,(Y_h-Y_l))}{(q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h})^2}.
\end{aligned}$$

The signs of the first three derivatives are unambiguous. For the fourth derivative,

$$\frac{dP}{dY_h} > 0 \iff q\,e^{\rho\,Y_l} + (1-q)\,e^{\rho\,Y_h}\,\,(1-\rho\,(Y_h-Y_l)) > 0.$$

The sign of the term is ambiguous. If ρ is large (or the difference $Y_h - Y_l$ is large), the second addend turns negative, and it also dominates the first addend. If ρ is small (or the difference $Y_h - Y_l$ is small), both addends are positive. One can also give a condition for whether the derivative is positive, but unfortunately it involves a non-standard function, the product-log (plog y gives the x that solves the equation $y = x\,e^x$). Then the derivative is positive if and only if $Y_h - Y_l < \big(1 + \operatorname{plog}[e^{-1}\,q/(1-q)]\big)/\rho$.

We want to stress two points. First, the property that dP/dY_h can turn negative is not unique to the choice of the utility function (see the argument below). Second, it is not a necessary condition for the main results of the paper. A more important property is the concavity of P in Y_h. But why can dP/dY_h turn negative at all? If the payout Y_h is high, investors get a high return in the good state. Their marginal utility is thus low, and they want to move consumption from the good to the bad state. They can do this by buying less assets, and storing more. But the supply of assets is fixed, hence the price drops. This is a standard microeconomic phenomenon; for sufficiently large risk aversion, consumption behaves like a Giffen good.

The property that the dP/dY_h reaches a maximum at some Y_h is not specific to exponential utility functions of investors. Consider constant relative risk aversion, $u(c) = c^{1-\rho}$, with $\rho > 1$. The relative risk aversion is then $\rho > 1$. Analogous to (2), we then get

$$\left.\frac{\partial u(P,\alpha)}{\partial \alpha}\right|_{\alpha=1} = (1-\rho)\, q\, (Y_h - P)\, (W + Y_h - P)^{-\rho} \\ + (1-\rho)\, (1-q)\, (Y_l - P)\, (W + Y_l - P)^{-\rho}. \tag{14}$$

If the market clears, this term (14) must be equal to zero. Due to risk aversion, the price P cannot exceed the expected yield, $P \leq q\, Y_h + (1-q)\, Y_l$. As a consequence, $(Y_h - P)\, (W + Y_h - P)^{-\rho} \to 0$ as $Y_h \to \infty$. However, this implies that $(Y_l - P)\, (W + Y_l - P)^{-\rho}$ must converge to zero for $Y_h \to \infty$, which is only possible if $P \to Y_l$. This proves that the function $P(Y_h)$ cannot be monotonic if the relative risk aversion ρ exceeds 1. ■

Proof of Lemma 2: If $\theta = 0$, then $\Pr\{s = h\} = 1/2$, $\Pr\{Y = Y_h | s = h\} = q$, and $\Pr\{Y = Y_h | s = l\} = q$. The signal contains no information; nothing can be learned. Consequently, $P_h = P_l$, and hence

$$P_0 = \frac{q\, Y_h\, e^{-\rho\, (Y_h - Y_l)} + (1-p)\, Y_l}{q\, e^{-\rho\, (Y_h - Y_l)} + (1-q)}$$

as in (2). Now consider the second case, $\theta = 1$. Then $\Pr\{s = h\} = q$, $\Pr\{Y = Y_h | s = h\} = 1$, and $\Pr\{Y = Y_h | s = l\} = 0$. As a result, $P_h = Y_h$ and $P_l = Y_l$, and P_0 is exactly as above. Hence, P_0 is independent of whether $\theta = 0$ or $\theta = 1$. ■

Proof of Lemma 3: The first statement is obvious. For the second statement, first look at the one-period case,

$$P(c\, Y_h, 0, \rho, q, \theta) = \frac{q\, c\, Y_h\, e^{-\rho\, c\, Y_h}}{q\, e^{-\rho\, Y_h} + (1-q)} = c\, P(Y_h, 0, c\, \rho, q, \theta).$$

This result immediately carries through to the two-period case. ■

Proof of Proposition 1: We want to distinguish between the two cases of Figure 2. Both have $dP_0/d\theta|_{\theta=0} = 0$; this can easily be shown analytically. Hence, to see whether the function increases or decreases around $\theta = 0$, consider the second derivative at the origin,

$$\left.\frac{d^2 P_0}{d\theta^2}\right|_{\theta=0} = 8\, e^{\rho}\, q^2\, (1-q)^2\, \lambda\, \rho\, \frac{e^{2\rho}\, (1-q) - q - e^{\rho}(1 - 2\, q + \rho)}{(e^{\rho}\, (1-q) + q)^4}.$$

This term is positive if (8) holds. Consequently, $P_0(\theta)$ increases around $\theta = 0$, but $P_0(1) = P_0(0)$. Because $P_0(\theta)$ is differentiable, there must be an interior optimum. ■

Proof of Lemma 4: We first want to argue that, ex ante, each cohort of investors wants to bear as much risk as possible. Look at one cohort only, and set $W = 0$ without loss of generality. Furthermore, set $Y_h = \bar{Y} + (1-p)\,\epsilon$ and $Y_l = \bar{Y} - p\,\epsilon$, such that the mean is always $\bar{Y}$, and ϵ measures (lack of) information before the trade. Then, substituting (2) into (1) with $\alpha = 1$ due to market clearing, we receive

$$u = -\Big((1-p)\,e^{\frac{p\,\epsilon\,\rho}{(1-p)\,e^{\epsilon\,\rho}+p}} + p\,e^{\frac{-(1-p)\,\epsilon\,\rho}{p\,e^{-\epsilon\,\rho}+(1-p)}}\Big),$$

$\bar{Y}$ drops out of the equation. The derivative with respect to ϵ is

$$\frac{\partial u}{\partial \epsilon} = \frac{(1-p)\,p\,\epsilon\,\rho^2\,e^{\frac{p\,\epsilon\,\rho}{(1-p)\,e^{\epsilon\,\rho}+p}}}{(1-p)\,e^{\epsilon\,\rho}+p},$$

which is positive for $\epsilon > 0$. As a consequence, higher risk raises utility (ex ante). Now take the ex interim perspective, i. e., keep the price fixed. Then (1) with $\alpha = 1$ yields

$$u = -\big(p + (1-p)\,e^{\epsilon\,\rho}\big)\,e^{(P-\bar{Y})-(1-p)\,\epsilon}.$$

The derivative with respect to ϵ is now

$$\frac{\partial u}{\partial \epsilon} = \rho\,p\,(1-p)\,(1-e^{\epsilon\,\rho})\,e^{(P-\bar{Y})-(1-p)\,\epsilon},$$

which is negative for $\epsilon > 0$. Hence, higher risk decreases utility ex interim. The argument, as it stands, applies to early and late investors. Hence, ex ante, early investors find $\theta = 1$ optimal; late investors like $\theta = 0$ best. Ex interim, preferences are reversed. ■

Proof of Proposition 2: The proof is structurally similar to that of Proposition 1. Let $\mathcal{U} = U_M + U_L$ denote the sum of the two utilities. From Figure 5, we have two examples where $U_M + M_L$ is hump-shaped in θ and reaches its optimum for some $\theta^* \in (0;\ 1)$. Now $d\mathcal{U}(\theta)/d\theta = 0$ for $\theta = 0$. For the two examples, $d^2\mathcal{U}(\theta)/d\theta^2 > 0$ at the point $\theta = 0$. Hence, in order to turn into a U-shaped function, $d^2\mathcal{U}(\theta)/d\theta^2$ would have to vanish at $\theta = 0$ for some parameter constellation (ρ, q). However,

$$\frac{d^2\mathcal{U}}{d\theta^2}\Big|_{\theta=0} = 4\,e^{\frac{q\,\rho}{e^{\rho}(1-q)+q}}\,\frac{(1-q)^2\,q^2\,\rho^2}{(e^{\rho}(1-q)+q)^4}\Big(e^{\frac{(2e^{\rho}(1-q)+q)\rho}{e^{\rho}(1-q)+q}} - e^{2\rho}(1-q) - e^{\rho}q\Big).$$

All terms are clearly positive, except for the large bracket term. But the bracket term is larger than

$$\Big(e^{\frac{(e^{\rho}(1-q)+q)\rho}{e^{\rho}(1-q)+q}} - e^{2\rho}(1-q) - e^{\rho}q\Big) = e^{\rho}(1-q)(1-e^{\rho}),$$

which is also positive. Hence, the second derivative is positive, which implies that the welfare function is increasing for small values of θ, which implies that it must exhibit in interior maximum. ■

Proof of Remark 1: The fact that the distribution's mean does not enter into the optimal disclosure policy follows from the first property of Lemma 3. The rest of the proof follows immediately from the conversion of statistical moments into model parameters, see (10). An increase in the variance has the same effect as an increase in risk aversion. The relation between q and the skewness ν is negative. To see this, take the derivative of (10),

$$\frac{\partial q}{\partial \nu} = -\frac{2}{(4+\nu^2)^{3/2}} < 0.$$

Ceteris paribus, a *higher* skewness is equivalent to a *lower* q. ■

Proof of Remark 2: Without loss of generality, set $Y_h = 1$ and $Y_l = 0$. The market price is determined by the clearing condition, $\partial u(P_0, \alpha)/\partial \alpha = 0$ for $\alpha = 1$, where $u(P_0, \alpha)$ is given by (11), hence it also depends on liquidity λ. We are interested in how the properties of $P_0(\theta)$ depend on λ. As in the proof of Proposition 1, we want to know whether the second derivative $\partial^2 P_0(\theta)/\partial\theta^2$ is positive or negative at the origin $\theta = 0$. Use (2) to see that the equilibrium price at the origin $\theta = 0$ is

$$P_0 = \frac{q}{q + e^{-\rho}\,(1-q)}.$$

Entering this into $\partial^2 P_0(\theta)/\partial\theta^2$ gives

$$\left.\frac{d^2 P_0}{d\theta^2}\right|_{\theta=0} = 8\,e^{\rho}\,q^2\,(1-q)^2\,\lambda\,\rho\,\frac{e^{2\,\rho}\,(1-q) - q - e^{\rho}(1-2\,q+\rho)}{(e^{\rho}\,(1-q)+q)^4}.$$

Apart from the factor λ, this term is identical to (15). Consequently, the root is the same. The term is positive when (8) holds. Consequently, $P_0(\theta)$ increases around $\theta = 0$, but $P_0(1) = P_0(0)$. Because $P_0(\theta)$ is differentiable, there must be an interior optimum. ■

Proof of Remark 3: Concentrate on one period first, and set $r = 0$ without loss of generality. The expected utility of an agent is then

$$\begin{aligned} u(P,\alpha) &= q\,E\Big[u\big[(w-\alpha\,P) + \alpha\,Y_h + X\big]\Big] + (1-q)\,E\Big[u\big[(w-\alpha\,P) + \alpha\,Y_l + X\big]\Big] \\ &= q \int e^{-\rho\,[(w-\alpha\,P)+\alpha\,Y_h+X]}\,dF(X) + (1-q)\int e^{-\rho\,[(w-\alpha\,P)+\alpha\,Y_l+X]}\,dF(X) \\ &= \Big[q\,e^{-\rho\,[(w-\alpha\,P)+\alpha\,Y_h]} + (1-q)\,e^{-\rho\,[(w-\alpha\,P)+\alpha\,Y_l]}\Big]\cdot\int e^{-\rho\,X}\,dF(X). \qquad (15) \end{aligned}$$

When taking the derivative for the first order condition, the integral over X drops out. As a result, the equilibrium price for the asset is exactly like in (2). But this also implies that the function $P_0(\theta)$ is not changed at all by the existence of additional risk. Hence, whether the function exhibits a minimum or maximum is not affected by further outside risk. ■

B Normally Distributed Payoffs

In the main paper, we have argued that the commitment to disclose *some* information at an interim period can maximize, but also minimize the ex ante market prices. For tractability we have assumed CARA utility and a two-point distribution for the payoff of the risky asset. We have also argued that the property of an inner minimum (or maximum) depends mainly on the investors' utility functions and on the variance and skewness of the return distribution. However, in the model, (i) the final profit could take only two values, and (ii) the utility function was exponential (CARA).

We can show that, if agents have logarithmic utility and the payoff distribution is discrete, then we also obtain the result that partial disclosure of interim information minimizes ex ante asset prices. If all agents have CARA utility and the payoff distribution is normal then ex ante asset price is independent of disclosure policy. But in general, point (i) is not easy to generalize, for the following reason. We need a model with some random variable, where some information is published in advance. If Bayesian learning should some tractable algebraic structure, then the final payoff and the signal should be normally distributed. But then there is no skewness, so we cannot make the claim that skewness matters. A model with discrete payoffs and discrete signals is more tractable, so we have chosen that the parametrization.

For the assumption (ii) of exponential utility, however, there is a tractable generalization. Assume that the final payoff is $\mu + \epsilon_1 + \epsilon_2$, where ϵ_1 and ϵ_2 are *normally distributed* with zero mean and standard deviation σ_1 and σ_2, respectively. The standard deviation of the aggregate payoff is thus $\sigma = \sqrt{\sigma_1^2 + \sigma_2^2}$. At date $t = 0$, investors only know μ. At date $t = 1$, they learn $\mu + \epsilon_1$. Keeping σ constant, the variable σ_1 measures the transparency of the firm's disclosure policy. For $\sigma_1 = \sigma_2 = \sigma/\sqrt{2}$, half of the information is disclosed at date $t = 1$, the rest is learned at date $t = 2$.

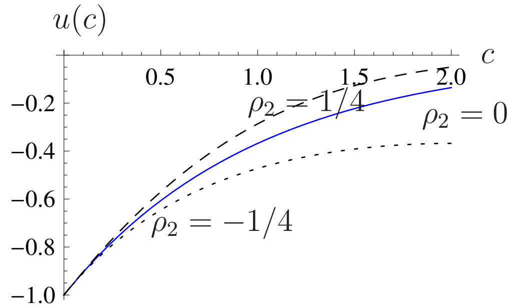
Assume that investors have the utility function $u(c) = -\exp(-\rho_1\, c - \rho_2\, c^2)$. For $\rho_2 = 0$, we have a constant absolute risk aversion of ρ_1. In general,

$$\frac{\partial}{\partial c}[\text{ARA}] = \frac{\partial}{\partial c}\Big[-\frac{u''(c)}{u'(c)}\Big] = 2\,\rho_2\,\frac{\rho_1^2 + 4\,c\,\rho_1\,\rho_2 + 2\,\rho_2\,(1 + 2\,c^2\,\rho_2)}{(\rho_1 + 2\,c\,\rho_2)^2}. \tag{16}$$

Hence for $\rho_2 > 0$, absolute risk aversion increases, otherwise it decreases. Note also that $u'(c)$ is positive only for $\rho_1 + 2\,c\,\rho_2 > 0$. For negative ρ_2, consumption c must hence not become too small. We keep this in the back of our mind. Figure 6shows a picture of possible utility functions. Parameters are always $\rho_1 = 1$. The solid curve has $\rho_2 = 0$, hence constant absolute risk aversion. The dashed curve has $\rho_2 = 1/4$ (increasing ARA), the dotted curve has $\rho_2 = -1/4$ (decreasing ARA).

We construct the initial price P_0 in two steps, as in the main text. First, we consider just one period with noise ϵ (with standard deviation σ). We will then get an equation for the assets price P at the beginning of that period. We can iterate the equation to get a

Figure 6: Market Value Maximizing Policy



general equation for P_0. We then look for extrema of P_0 as a function of σ_1. For the first step, consider an investor's expected utility depending on his investment into the risky asset, take the first order condition, and then take into account market clearing. The resulting price is

$$P = \mu - \frac{1}{4\,\rho_2}\left(\sqrt{(1+2\,\rho_2\,\sigma^2)\big(\rho_w^2\,(1+2\,\rho_2\,\sigma^2) - 16\,\rho_2^2\,\sigma^2\big)} - \rho_w\,(1-2\,\rho_2\,\sigma^2)\right) \tag{17}$$

with $\rho_w := \rho_1 + 2\,w\,\rho_2$. For $\rho_2 = 0$, this term becomes simply $P = \mu - \rho_1\,\sigma^2$. Now we carry out the backward induction. At date $t = 1$, depending on the realization of ϵ_1, the price will be

$$P_1 = \mu + \epsilon_1 - \frac{1}{4\,\rho_2}\left(\sqrt{(1+2\,\rho_2\,\sigma_2^2)\big(\rho_w^2\,(1+2\,\rho_2\,\sigma_2^2) - 16\,\rho_2^2\,\sigma_2^2\big)} - \rho_w\,(1-2\,\rho_2\,\sigma_2^2)\right). \tag{18}$$

As a consequence, from the perspective of date $t = 0$, the price P_1 is also normally distributed with mean

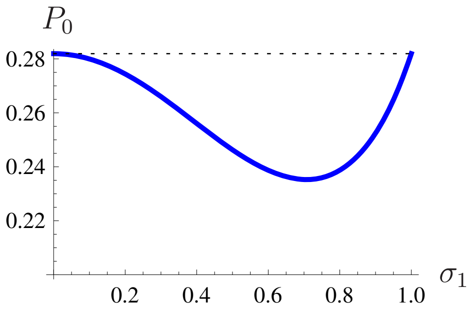
$$\mu - \frac{1}{4\,\rho_2}\left(\sqrt{(1+2\,\rho_2\,\sigma_2^2)\big(\rho_w^2\,(1+2\,\rho_2\,\sigma_2^2) - 16\,\rho_2^2\,\sigma_2^2\big)} - \rho_w\,(1-2\,\rho_2\,\sigma_2^2)\right) \tag{19}$$

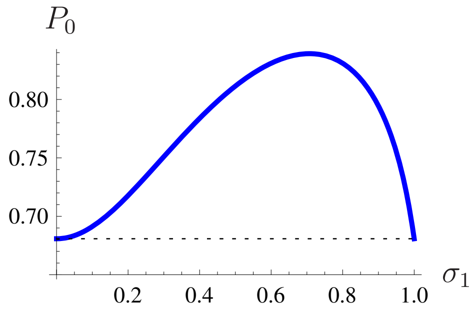
and standard deviation σ_1. The price P_0 is thus

$$\begin{aligned} P_0 = \mu &- \frac{1}{4\,\rho_2}\left(\sqrt{(1+2\,\rho_2\,\sigma_2^2)\big(\rho_w^2\,(1+2\,\rho_2\,\sigma_2^2) - 16\,\rho_2^2\,\sigma_2^2\big)} - \rho_w\,(1-2\,\rho_2\,\sigma_2^2)\right) \\ &- \frac{1}{4\,\rho_2}\left(\sqrt{(1+2\,\rho_2\,\sigma_1^2)\big(\rho_w^2\,(1+2\,\rho_2\,\sigma_1^2) - 16\,\rho_2^2\,\sigma_1^2\big)} - \rho_w\,(1-2\,\rho_2\,\sigma_1^2)\right). \end{aligned} \tag{20}$$

Now the aggregate risk is $\sigma^2 = \sigma_1^2 + \sigma_2^2$. We want to keep σ constant, thus substitute $\sigma_2^2 \mapsto \sigma^2 - \sigma_1^2$. Figure B shows possible shapes of the function $P_0(\sigma)$. In the left picture, for parameters $\rho_1 = 1$, $\sigma = 1$, $w = 1$, $\mu = 2$, and $\rho_2 = 5/7$, there is an inner minimum. In the right picture, for parameters $\rho_2 = -1/7$ (others as before), there is an inner maximum. These pictures are remarkably similar to those in Figure 2 in the main paper. This already suggests that the results do not depend on the functional form of utility functions and probability distributions.

We now ask the same question as in the main paper: when do we get an inner maximum or minimum, and where is that extremum? The answer is algebraically simple. $P_0'(\sigma_1) = 0$





if and only if $\sigma_1 = 0$ or $\sigma_1 = \sigma/\sqrt{2}$. The first point is an artefact (if we looked at $P_0(\sigma_1^2)$ instead of $P_0(\sigma_1)$, this solution would disappear). The second solution is due to the fact that P_0 is symmetric in σ_1 and σ_2. Therefore, $\sigma_1 = \sigma_2$ must be an extremum, hence $\sigma_1 = \sigma_2 = \sigma/\sqrt{2}$. Now to see whether the extremum is a minimum or maximum, consider the second order condition,

$$P_0''(\sigma_1 = \sigma/\sqrt{2}) = \frac{64\,\rho_2^3\,\sigma^2}{\left((1+2\,\rho_2\,\sigma_2^2)\,(\rho_w^2\,(1+2\,\rho_2\,\sigma_2^2)-8\,\rho_2\,\sigma^2)\right)^{3/2}}. \tag{21}$$

If this term is real (otherwise, the price P_0 does not exist in the first place), then it is positive for positive ρ_2, and vice versa. This proves the following proposition. Increasing absolute risk aversion thus promotes an inner maximum of $P_0(\theta)$, and Remark 1 shows that a positive skewness promotes an inner *minimum*. These results can be combined. For example, if investors have log-utility (decreasing absolute risk aversion), $P_0(\theta)$ would have an interior minimum if Y were distributed with a sufficiently negative skewness.

Proposition 3 *With the parametrization as above, the initial price P_0 has an inner maximum (minimum) at $\sigma_1 = \sigma_2 = \sigma/\sqrt{2}$ if and only if the investors' utility function has decreasing (increasing) absolute risk aversion.*

C Numerical Example

Consider the numerical example $Y_l = 0$, $Y_h = 1$, $q = 0.5$, and $\rho = 2$ (see Table 1 on page 30). The table shows how prices can evolve for five different levels of disclosure (five different values of θ). Without disclosure ($\theta = 0$), in equilibrium $P_0 = P_1 = 0.119$. M-investors bear no risk while L-investors bear full risk. If the final payoff is $Y_l = 0$, they suffer 100% loss. If the final payoff is $Y_h = 1$, they make a profit of 739%. Since investors are relatively risk averse, the potential profit is not valued that much.

By shifting some price risk to the M-investors ($\theta > 0$), this can increase the ex ante P_0 price. To illustrate the intuition, suppose that $\theta = 0.5$. In equilibrium, $P_0 = 0.136$. If investors obtain a low signal, then $P_{1L} = 0.043$. If the signal is high, then $P_{1H} = 0.289$.

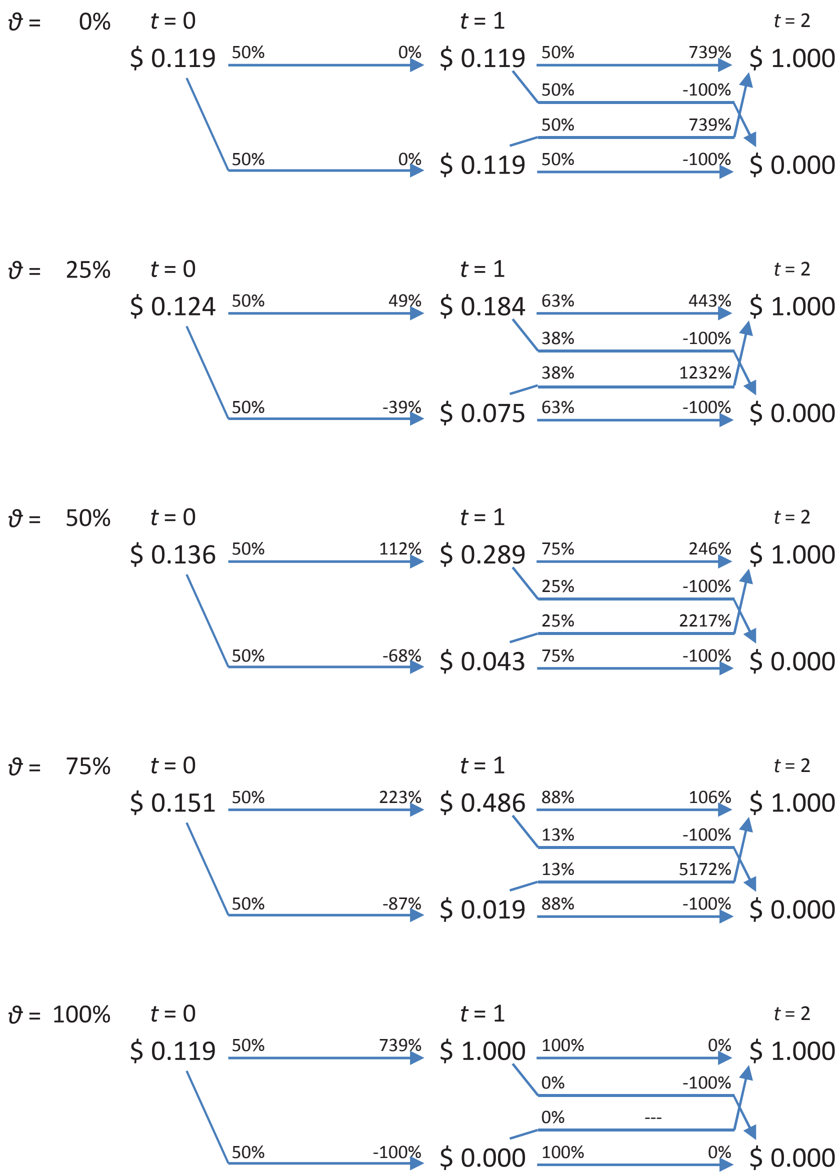
M-investors bear some risk now since they pay $P_0 = 0.136$ and can sell the asset either for $P_{1L} = 0.043$ (-68% loss) of for $P_{1H} = 0.289$ (112% profit). Now in the high signal state, the L-investors pay 0.289. If the final payoff is $Y_l = 0$, they still make 100% loss (as in the $\theta = 0$ case). But if the final payoff is $Y_h = 1$, they make 246% profit (instead of 740% when $\theta = 0$). This type of risk sharing increases ex ante market price.

The intuition for the possibility of an interior *minimum* when q is high and ρ is low goes as follows. Without interim disclosure, the date 1 price (and thus date 0 price) is close to the final payoff Y_h. Partial disclosure means that investors obtain a noisy interim signal which is wrong with positive probability. If the signal suggests that Y_l is likely to be the final payoff, then there is a relatively large price decline at date 1, such that the M-investors bear downside risk. But if the signal turns out to be wrong and the true state is Y_h, the L-investors experience a gain. Because of risk aversion, the potential price decline that the M-investors face at date 1 has a higher impact on the date 0 price than a potential price increase that L-Investors might experience at date 2. In such a case, partial disclosure causes prices to fluctuate at date 1. If there is no disclosure, L-investors bear all price risk while M-Investors face no risk.

Intuitively, for a disclosure policy to *minimizes* the value at $t = 0$, the sum of the risk premia that M- and L-investors demand is higher than the risk premium that one cohort of investors would demand when it bears all the risk. This argument explains why the function $P_0(\theta)$ has an interior minimum for high q and low ρ.

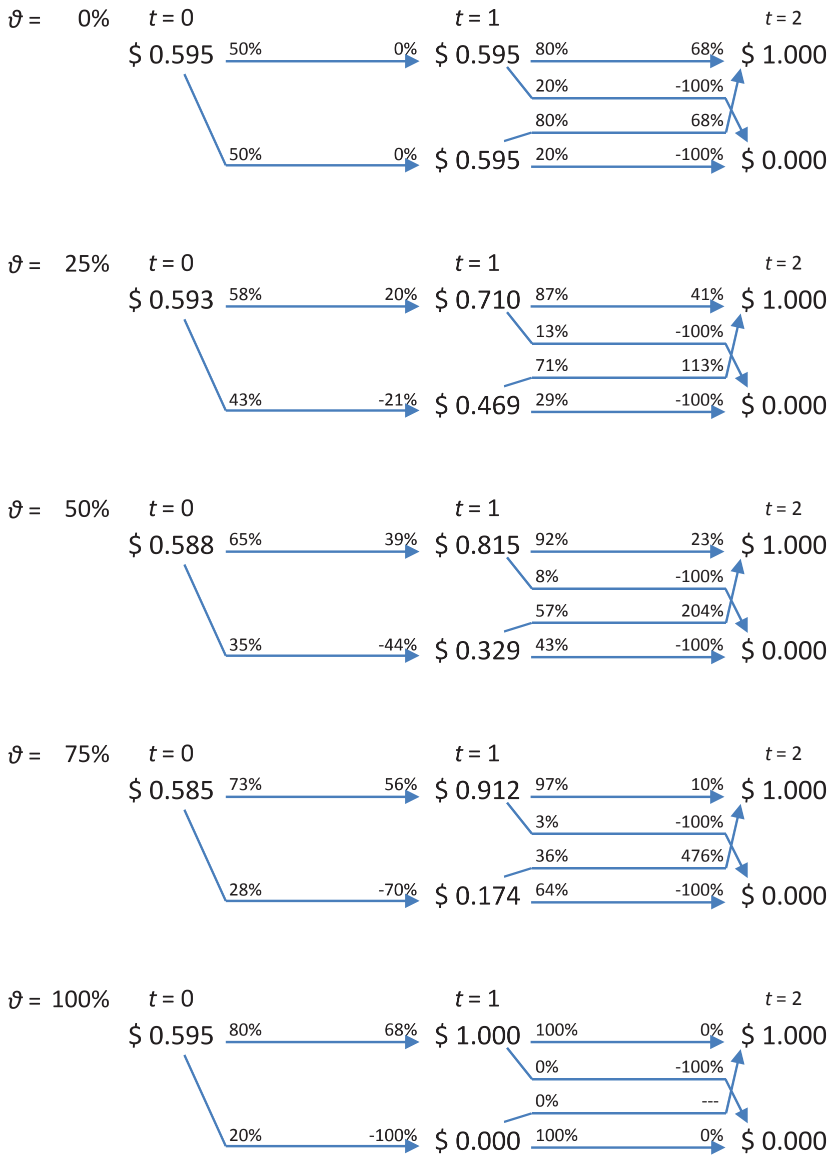
As a numerical example, consider the parameters $Y_l = 0$, $Y_h = 1$, $q = 0.9$, and $\rho = 1$ (see Table 2 on page 31). Without disclosure ($\theta = 0$), in equilibrium $P_0 = P_1 = 0.768$. M-investors bear no risk while L-investors bear full risk. If the final payoff is $Y_l = 0$, they suffer a 100% loss. If the final payoff is $Y_h = 1$, they make a profit of 30%. With partial disclosure, say $\theta = 0.5$, in equilibrium $P_0 = 0.754$, $P_{1L} = 0.321$ and $P_{1H} = 0.959$. So the M-investors also bear risk of either making a loss of -57% or a profit of 27%. With partial disclosure, if the signal is high at $t = 1$, L-investors makes a 100% loss (when the final payoff is Y_l) or a profit of 4% (when the final payoff is Y_h). If the signal is low at $t = 1$ and if $P_{1L} = 0.321$, L-investors make a profit of 211% (when the final payoff is Y_h). This type of risk sharing reduces ex ante market prices.

Table 1: Numerical Example with $\rho = 2.0$ and $q = 0.5$



In this numerical example, $Y_h = 1$, $Y_l = 0$, $\rho = 2.0$, $q = 0.5$, and θ varying between 0 and 1. In this case, there is an inner *maximum* at $\theta = 0.79$ with $P_0 = 0.1514$.

Table 2: Numerical Example with $\rho = 1.0$ and $q = 0.9$



In this numerical example, $Y_h = 1$, $Y_l = 0$, $\rho = 1.0$, $q = 0.9$, and θ varying between 0 and 1. In this case, there is an inner *minimum* at $\theta = 0.76$ with $P_0 = 0.5015$.

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