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## **Cursed financial innovation**

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Abstract

### ***Cursed financial innovation\****

We analyze the welfare properties of derivative securities that profit-maximizing issuers offer to investors who have inferior information and neglect the information content of the offer. To capture the markets for structured securities and exotic exchange-traded funds, we assume that issuers can choose both the underlying asset and the form of the security. An issuer's optimal security induces investors to bet on unlikely market movements, creating both excess risk taking and undersaving. Giving more information to the issuer leads it to choose an underlying asset on which its information is more extreme, exacerbating both effects and hence lowering social welfare. Furthermore, providing inferior and noisy additional information to investors also lowers welfare because the security is then written on an underlying asset about which the information is misleading. If the issuer can base its security on a combination of underlying assets, it optimally creates a “custom-designed” index to maximize its informational advantage and minimize risk, minimizing investor and social welfare. Restricting the set of underlying assets – a kind of standardization – increases welfare by preventing the issuer from systematically selling a security with extreme or misleading information. Once this policy is adopted, increasing investor information becomes beneficial.

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# 1 Introduction

Financial innovation has drastically changed households' balance sheets in the last few decades, and several researchers and policymakers have expressed concerns that if consumers are not fully sophisticated, this development may not always have been to their benefit. While a substantial body of work examines the implications of consumer naivete for credit products and liability-side innovations (Engel and McCoy, 2002; DellaVigna and Malmendier, 2004; Bar-Gill and Warren, 2008; Heidhues and Kőszegi, 2010, for example), however, there is no systematic analysis of the implications of naivete for asset-side innovations. Yet the asset side of the financial market has also seen substantial progress, with complex payoff structures and a wealth of instantly accessible financial information now widely available to non-professional investors.

In this paper, we analyze the implications of asset-side financial innovation and information when investors neglect that issuers are utilizing superior information in designing securities. Our approach is motivated by evidence and arguments that—analogously to the winner's curse in auctions—individuals in general and small investors in particular underestimate the information content of others' actions (Eyster and Rabin, 2005; Eyster et al., 2014). We argue that our framework naturally explains aspects of the market for structured retail products, exotic exchange-traded funds (ETF's) and custom-tailored collateralized debt obligations (CDO's), identify the welfare properties of securities traded in equilibrium, and consider welfare-increasing interventions. We show that rational profit-maximizing issuers induce investors to bet on unlikely market movements, creating both excess risk taking and undersaving. Further, under reasonable conditions improving *either* side's information lowers total welfare. As a result, an issuer prefers to write the security on underlying assets about which investors know more; and it favors more financially well-informed consumers and to give away some information. If the issuer can base its security on a combination of underlying assets, it optimally creates a “custom-designed” index to maximize its informational advantage and minimize risk, minimizing investor and social welfare. Market-based policies such as an increase in competition between issuers do not increase welfare. Restricting the set of underlying assets the issuer can use—a kind of standardization—raises welfare, and once this policy is adopted, increasing investor information becomes beneficial.

Section 2 presents our model, which has two periods. An investor with a strictly risk-averse utility function in period 2 can only save for that period through a risk-neutral issuer. There are a countable number of underlying assets whose payoffs are resolved in period 2, and the issuer and the investor start off with the same prior regarding these payoffs. In period 1, the issuer observes private information regarding the payoff of the assets, picks one as the underlying asset, and offers a derivative security—defined as a map from the payoff of the underlying asset to the payoff of the security—to the investor. The issuer’s informational advantage could derive, for instance, from access to a professional market for derivatives it also uses to hedge the security it offers. As a benchmark, we show that with rational investors the issuer always offers the first-best, constant-payoff security, which insures the investor and eliminates adverse selection in trading. But following Eyster and Rabin (2005), we posit that the investor is fully cursed: in considering her investment options, she neglects that the issuer’s offer depends on its private information.

We identify basic properties of the resulting security in Section 3, first taking as given the underlying asset the issuer chooses. Reminiscent of results in the literature on contracting with heterogeneous priors, the issuer’s optimal security offers overly high consumption in states whose probability the investor overestimates and overly low consumption in states whose probability the investor underestimates, thereby inducing suboptimal risk-taking. Even given the amount of risk the investor takes, however, she undersaves in that increasing her period-2 consumption by the same amount in every state would increase her expected utility. Complementing the traditional view that the increased availability of debt instruments may have led to undersaving for large parts of the population, therefore, our framework says that new investment opportunities may paradoxically have had the same effect.

To study other features of equilibrium, we assume that the investor’s utility takes the log form. With log utility, total social welfare (combining the issuer’s expected profit and the investor’s expected utility) conveniently turns out to be a decreasing function of the Kullback-Leibler (KL) divergence of the investor’s beliefs from the issuer’s beliefs, and the issuer’s expected profit turns out to be an increasing function of the KL divergence of the issuer’s beliefs from the investor’s beliefs.<sup>1</sup> Using this connection, we show that to maximize the divergence

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<sup>1</sup> A related result in information theory is that if returns follow the distribution  $f(\cdot)$ , then the Kullback-Leibler divergence between  $f(\cdot)$  and  $g(\cdot)$  is an upper bound on the utility loss an investor with log utility can

between the parties' beliefs and hence profit, the issuer chooses as the underlying asset an asset on which it has extreme—the best or worst possible—information. A crucial aspect of this prediction is that the investor ignores how the underlying asset is selected. Although such ignorance is a—not previously noted or studied—logical implication of cursedness, we also mention some direct evidence that individuals neglect related selection effects.

Motivated by the observation that part of the recent development in financial markets is the increased ease of acquiring basic information on investments, in Section 4 we turn to investigating the effect of providing more information to parties. If the issuer becomes more informed, then its most extreme possible signal becomes more extreme, increasing the KL divergence between the parties' beliefs and thereby raising profits and lowering total welfare. Making the professional market more informationally efficient, therefore, lowers social welfare in the retail market.

Furthermore, an improvement in the investor's information also raises profits and lowers social welfare so long as—realistically—the information is inferior to the issuer's and sufficiently noisy. Intuitively, the issuer now chooses an underlying asset on which it has extreme information (as before) *and* the investor's information goes in the opposite direction. This generates a kind of discontinuity: if the investor receives exactly the same information as the issuer, then social welfare is maximized and hence discretely higher than without information; but if the investor receives noisy information very close but inferior to the issuer's information, welfare may be discretely lower than without information.

The above insight has several potentially important implications. A positive prediction is that an issuer prefers to write its security on an underlying asset in the public eye, and it also likes to give away some of its information. A central welfare implication is that the increased availability of financial information may have hurt small investors. To make things worse, since investors believe that information will allow them to make better choices, they are even willing to spend effort or resources to acquire such welfare-decreasing information. In addition, investors who are savvy enough to become more informed (but not less cursed) are worse off than more naive investors. And since giving information to investors that the issuer does not have seems impossible in practice, information-based policies to improve investor and

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suffer from picking an optimal portfolio under the belief  $g(\cdot)$  rather than  $f(\cdot)$  (Cover and Thomas, 2012, Theorem 16.4.1).

social welfare are likely to backfire.

In Section 5, we identify one simple intervention that increases social welfare. Namely, we propose a kind of standardization: the planner selects one asset, and requires that any security be based on that underlying asset. This intervention takes away the issuer’s ability to choose an underlying asset on which it has extreme information, and because this tends to decrease the divergence between the parties’ beliefs, it tends to increase welfare. Furthermore, once standardization is adopted, giving the investor more information also raises welfare. Intuitively, information moves an investor’s beliefs closer to the issuer’s on average, and without the issuer being able to choose a rare underlying asset on which the investor received misleading information, this increases welfare.

In Section 6, we consider extensions and modifications of our basic framework. We begin by allowing for the issuer to base its security on a combination of existing assets. The issuer can then choose a custom-designed “index” that the investor believes is representative but that is actually based on assets about which the issuer has negative information. Since the index eliminates idiosyncratic risk, this construction facilitates a large bet between the parties, maximizing profits and minimizing investor and social welfare.

We also point out that our model has an equivalent—but in our view far less well-motivated—restatement in a world with rational agents and heterogenous priors, raising the question of whether our welfare results hold when evaluated based on the investor’s beliefs. While the level of saving is then just right, we argue that the logic of all our other basic results remains unchanged.

Finally, we consider the effects of competition on our basic results, showing that the main determinant of welfare is not the presence or market power of issuers, but the ability to tailor investment positions precisely in the way parties want: if competitive issuers design the security or the investor does so herself, the same security results. And while competitive markets lower prices for investors, we point out that if information is costly and investors make an endogenous decision whether to acquire it, then competition reduces total welfare. Given that competition leaves all of the perceived surplus from the transaction with the investor, it increases the perceived gain from information, and hence increases the incentive for acquiring welfare-reducing information.

Our model describes the markets for three important types of financial products. The monopoly version fits the market for structured retail investments, a large and fast-growing market of €3.4 trillion (Bergstresser, 2008) offering directional bets on stocks, exchange rates, and indices. Typically, investors purchase these securities from their retail banks at a stage when banks likely enjoy substantial market power, and an investment bank holds the opposite side. Consistent with our perspective, Bergstresser (2008) and especially Henderson and Pearson (2011) argue that structured securities make no economic sense and are overpriced to an extent that their expected returns may be negative. Furthermore, our prediction that structured securities are written on assets in the public eye is consistent with casual observation and evidence by Henderson and Pearson (2011).

The competitive version of our model fits the fast-growing US market for exotic exchange-traded funds (ETFs), which investors can purchase directly on the—likely quite competitive—financial market to take leveraged positions or other directional bets on a wide range of underlying assets. Exotic ETFs and structured securities provide investors with similar payoff structures. From this perspective, a possible explanation for the relatively small size of the US market for structured securities documented by Célérier and Vallée (2014) is that investors are buying exotic ETFs to achieve the same investment goals. Our model says that exotic ETF's are cheaper than structured securities, but do not provide better payoff structures.

The version of our model where the issuer custom-designs the underlying asset can be reinterpreted by assuming that the investor—rather than ignoring the informational content of the offer of an issuer she knows to be informed—falsely believes that an uninformed party is designing the index, when in fact an informed party is. Under this interpretation, our model describes some custom-tailored CDO's, such as the Goldman Sachs ABACUS deal.

## 2 Basic Model

### 2.1 Setup

In this section, we introduce our basic model. There are two periods,  $t = 1, 2$ , and a countable number of underlying assets such as individual stocks, indices, or exchange rates. For each asset  $i$ , there is an asset-specific state  $n \in \{1, \dots, N\}$  that is realized in period 2, with asset

$i$  paying  $s_n^i$  in state  $n$ . The parties' priors regarding the states are the same. In period 1, the issuer receives a private signal  $y^i \in \{y_1, \dots, y_M\}$  about each asset  $i$ . The assets have independent payoffs, and the signals  $y^i$  are also independent across assets. We denote prior probabilities by  $f(\cdot)$  and posterior probabilities by  $f(\cdot|\cdot)$ . The prior and the issuer's signals are symmetric across assets:  $f(s_n^i) = f(s_n^j)$  and  $f(s_n^i|y_m) = f(s_n^j|y_m)$  for any  $i, j, n, m$ , where  $f(s_n^i|y_m)$  is shorthand for  $f(s_n^i|y^i = y_m)$ . Our assumptions that there are countably many assets and that they are independent and symmetric serve to make our points in a clean form, but it will be clear that the mechanisms we identify hold more generally.

We impose that the issuer's information is directional—any signal is either good news or bad news about the underlying state relative to the prior, and signals can be ranked in terms of how good news they are:

**Definition 1.** The information  $y^i$  is directional if  $f(s_n^i|y_m)/f(s_n^i|y_{m'})$  is strictly decreasing for any  $y_m, y_{m'}$  with  $m' > m$ , and  $f(s_n^i|y_m)/f(s_n^i)$  is monotone for any  $y_m$ .

Given our analysis below, most structured securities and exotic ETFs on the market are consistent with our assumption of directional information. Exactly as our model predicts, these securities typically have monotonic payoff profiles. Furthermore, many other securities are also consistent with directional information after a trivial redefinition of the states. For example, a derivative that is a monotonic bet on the change of the value of a given underlying asset is consistent with our model when thinking of  $s_n^i$  as the relevant change in value.

In period 1, the parties can trade a derivative security that pays off in period 2. After observing its private information, the issuer chooses one underlying asset  $i$ , a security  $c^i = (c_1^i, \dots, c_N^i)$  mapping states  $s_n^i$  to payoffs  $c_n^i$ , and a price  $p$ , and the investor decides whether to purchase the security.<sup>2</sup> The issuer is risk-neutral, and can acquire funds at zero interest. In period 1, the investor's utility is linear with a slope of 1, and in period 2, she has a strictly concave utility function  $u(\cdot)$  satisfying  $u'(0) = \infty$  and  $\lim_{c \rightarrow \infty} u'(c) = 0$ . Her income in period 2 is  $\underline{c}$  in every state, and the issuer's security is her only opportunity to save.

Our assumption that the issuer must pick a single underlying asset captures the fact that the vast majority of structured securities and exotic exchange-traded funds are written on

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<sup>2</sup> As we will argue, whether the issuer chooses the functional form of the security before or after observing its private signals is immaterial. It is, however, important that the issuer chooses the underlying asset after observing the signals.

single pre-existing assets and measures. As we show in Section 6.1, however, in our model the issuer would rather create its own “custom-designed” index and write the security on this index, raising the question of why issuers use single pre-existing assets. There are practical reasons outside the model that could make more complicated securities prohibitively difficult to sell in the retail market. For instance, it may be difficult to explain or market derivatives written on custom-designed indices to small investors.

While the issuer’s informational advantage could derive from multiple sources, one possibility is that—unlike the investor—it observes and takes into account the information content of prices in the professional market for derivatives. This is especially likely to be the case if the issuer also uses the professional market to hedge the security it sells. In fact, a model equivalent to ours arises if the issuer has no (direct) informational advantage, but can trade in both the professional market and the retail market, and  $f(s_n^i|y^i)$  is the professional-market price of an Arrow-Debreu security providing a unit of consumption in state  $s_n^i$ . From this perspective, an informationally more efficient professional market induces a greater informational advantage for the issuer in the retail market.

We assume that the investor is fully cursed in the sense of Eyster and Rabin (2005), which in this case means that she neglects to account for disagreements between herself and the issuer in evaluating the security. As a result, when deciding whether to accept the issuer’s offer, the investor evaluates the security according to the prior distribution  $f(s_n^i)$ , and does not take into account what the security reveals about the issuer’s private information.

Note that in our setting, the first-best security has  $u'(c_n^i + \underline{c}) = 1$  in every state, equating the investor’s marginal benefit of saving with the social cost of funds. The choice of the underlying asset is immaterial. This also implies that with the first-best security, the Euler equation  $E[u'(c_n^i + \underline{c})|y^i] = 1$  holds—the marginal utility of consumption today (which is 1) equals the expected marginal utility of saving more for tomorrow at the gross interest rate of 1.

## 2.2 Benchmark: Rational Investor

As a benchmark, we discuss the case of a fully rational investor. Then, the parties achieve first-best:

**Proposition 1.** *If the investor is rational, then there is a unique perfect Bayesian equilibrium,*

and in this equilibrium the issuer offers a first-best security with probability one.

With rational investors, both risk aversion and adverse selection call for a flat security. If the issuer offered a security that is increasing in the state, for instance, the investor would both dislike it due to the risk it imposes on her, and be worried that the issuer only offers the security because the state is likely to be low. A direct implication of Proposition 1 is that with rational investors, information—no matter which party observes how much—has no effect on outcomes.

### 3 Basic Properties of the Issuer’s Optimal Security

#### 3.1 Issuer’s Optimal Security Given an Underlying Asset

We first derive some basic properties of the issuer’s optimal security taking as given the underlying asset  $i$ , and later turn to considering the choice of  $i$ . This initial step mirrors many previous analyses of the effects of differences in beliefs on contracting (Harrison and Kreps, 1978; Morris, 1996; Geanakoplos, 2010; Simsek, 2014, for example). Since the investor believes that the probability of state  $s_n^i$  is  $f(s_n^i)$ , the maximum price at which she is willing to buy the security  $(c_1^i, \dots, c_N^i)$ , and hence the price at which the issuer sells the security, is

$$p = \sum_n f(s_n^i) u(c_n^i + \underline{c}) - u(\underline{c}). \quad (1)$$

This implies that in designing the security, the issuer solves

$$\max_{c^i} p - \sum_n f(s_n^i | y^i) c_n^i = \sum_n [f(s_n^i) u(c_n^i + \underline{c}) - f(s_n^i | y^i) c_n^i] - u(\underline{c}). \quad (2)$$

Taking the first-order condition with respect to  $c_n^i$  yields the following lemma:

**Lemma 1.** *Given the underlying asset  $i$ , the security that is uniquely optimal for the issuer is given by*

$$u'(c_n^i + \underline{c}) = \frac{f(s_n^i | y^i)}{f(s_n^i)}. \quad (3)$$

The optimal security induces overconsumption in states that the investor considers more likely than the issuer, and underconsumption in states that the investor considers less likely

than the issuer. In other words, the investor takes a bet with the issuer that is a function of their differences in opinion.

### 3.2 Undersaving

In addition to implying excess risk taking, Lemma 1 has a mathematically simple, but economically important implication:

**Proposition 2.** *Whichever underlying asset  $i$  the issuer chooses, the optimal security generates undersaving by the investor:  $E[u'(c^i)|y^i] > 1$ .*

The optimal security induces the investor to undersave in the sense that saving a little more in every state would increase her expected utility. Intuitively, the issuer lowers consumption below optimal in states that are more likely, leading to overly low consumption on average.

It has long been recognized that innovations on the credit side of the financial market, such as the increased availability of credit cards and payday loans, could have contributed to undersaving among consumers with a taste for immediate gratification (Laibson, 1997, for example). Complementing this view, our framework highlights that innovations on the investment side of the financial market could—paradoxically—also have contributed to undersaving, even among time-consistent consumers.

Note that the resulting consumption profile would not change if the investor had access to a competitive market for bonds, which would allow her to transfer consumption to the future at an interest rate of zero and hence mitigate or eliminate her undersaving. To see this, suppose that the investor buys the security identified in Lemma 1. It is easy to argue that she would then strictly prefer not to trade in the bond market. If she weakly preferred to take a non-zero position in bonds in addition, then her net position would generate a consumption profile that would be optimal for the issuer to offer. But this contradicts that the above security is uniquely optimal for the issuer.<sup>3</sup>

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<sup>3</sup> While a market for bonds does not change the period-2 consumption profile, it does affect the investor's outside option. If the investor did not buy a security from the issuer, she would buy the first-best amount of bonds, resulting in riskless consumption  $c$  satisfying  $u'(c) = 1$ . This is equivalent to our basic model with  $u'(\underline{c}) = 1$ . But although the investor's outside option is first-best, the issuer can profitably trade with her: since the issuer breaks even by offering her the first-best amount of bonds, it makes positive profits with the unique optimal security above.

### 3.3 Log Utility and Relative Entropy

For tractability, for the rest of the paper we assume that utility takes the log form:  $u(c) = \ln(c)$ . Furthermore, because this will be central in a number of our results, we introduce notation to keep track of the information the parties have. For any variable that depends on information, we allow for two arguments that stand for the issuer's and investor's signals, respectively. Hence,  $c^i(y^i, \emptyset)$  is the optimal security written on underlying asset  $i$  when the issuer has observed  $y^i$  and the investor has observed no signal. Then, Equation (3) yields

$$c_n^i(y^i, \emptyset) = \frac{f(s_n^i)}{f(s_n^i|y^i)} - \underline{c}. \quad (4)$$

With log utility, expected welfare and profit conveniently reduce to simple linear functions of appropriate relative entropy measures. The *relative entropy* of distribution  $g$  with respect to distribution  $h$ , or *Kullback-Leibler (KL) divergence* of  $h$  from  $g$ , is  $D(g(c)||h(c)) \equiv \sum_c g(c) \ln(g(c)/h(c))$ . The KL divergence can be thought of as an unusual distance measure, which is always non-negative and zero if and only if  $f = g$ , but is not symmetric and does not satisfy the triangle inequality. Given the underlying asset  $i$ , we denote total social welfare—defined as the sum of the issuer's expected profit and the investor's expected utility—by  $W^i$ .

**Corollary 1.** For  $u(c) = \ln(c)$ ,

$$W^i(y^i, \emptyset) = -D(f(s_n^i|y^i)||f(s_n^i)) - 1 + \underline{c},$$

with the issuer's expected profit being

$$D(f(s_n^i)||f(s_n^i|y^i)) - 1 + \underline{c} - u(\underline{c}).$$

The first part says that expected social welfare is a decreasing function of the KL divergence of the issuer's beliefs from the investor's beliefs. Intuitively, the further are the parties' beliefs, the greater is the bet they take with each other, and hence the lower is welfare. The second part says that expected profit is an increasing function of the KL divergence of the investor's beliefs from the issuer's beliefs. Intuitively, the further are the investor's beliefs from the issuer's beliefs, the greater is the informational advantage the issuer enjoys, and hence the better it can exploit the investor with the appropriate security.

### 3.4 Selection of the Underlying Asset

We now turn to the issuer's choice of the underlying asset. Note first that because the issuer receives information that is independent across assets, for any realization  $y_m \in \{y_1, \dots, y_M\}$ , with probability one there is some  $i$  such that  $y^i = y_m$ . Hence, the issuer can effectively choose the realization of its private signal by picking the underlying asset. Proposition 3 shows that the issuer picks an underlying asset on which it has extreme information:

**Proposition 3.** *If the issuer designs the security on underlying asset  $i$ , then either  $y^i = y_1$  or  $y^i = y_M$ .*

Our assumption that  $y^i$  is directional implies that among all the underlying assets with good news, the issuer prefers one with the best news. Similarly, among all the assets with bad news, the issuer prefers one with the worst news. Intuitively, the more extreme is the signal  $y^i$ , the more distant are the parties' beliefs and hence the more profitable is the security the issuer can write.

A key factor in Proposition 3 is that the investor neglects how the underlying asset is selected. Besides it being an implication of cursedness, some direct evidence also indicates that individuals neglect related selection effects. For instance, Koehler and Mercer (2009) find that most mutual-fund companies selectively advertise their better-performing funds, yet both novice and professional investors *fully* ignore such strategic selection when this is not made transparent to them. Similarly, Brenner et al. (1996) find that individuals do not discount transparently one-sided evidence.

Of course, Proposition 3 does not identify which extreme signal the issuer prefers for its underlying asset. Using Corollary 1, the issuer strictly prefers  $y^i = y_1$  over  $y^i = y_M$  if and only if

$$D(f(s_n^i) || f(s_n^i | y_1)) > D(f(s_n^i) || f(s_n^i | y_M)). \quad (5)$$

The issuer prefers an underlying asset for which its signal is the worst possible rather than the best possible if its worst signal is stronger than its best signal, so that its worst possible beliefs are more extreme than its best possible beliefs. For the rest of the paper, we assume that providing additional information to either party does not change which of these two types of underlying assets the issuer prefers. Intuitively, this amounts to assuming that additional

information does not change whether the issuer’s best or worst signal is stronger relative to the investor’s beliefs. We state our results assuming that the issuer prefers an underlying asset with the worst signal; analogous results would hold if the opposite was the case.

One simple point regarding the timing of the issuer’s choices is worth emphasizing. While we have assumed that the issuer selects both the functional form of the security and the underlying asset after receiving information, outcomes remain unchanged if it announces the former—but not the latter—before receiving information. Since the issuer knows that it will choose an underlying asset with  $y^i = y_1$ , it knows the precise form the security will take. All the issuer has to do when it receives information, then, is to select the underlying asset to which the given form of security is to be applied. For example, the issuer can announce before period 1 that it will offer a reverse convertible of the type discussed in Henderson and Pearson (2011), but only in period 1 decide that the underlying stock will be Google.

## 4 The Effects of Information

One of our main interests in the paper is to explore the effects of providing more information to parties. We first consider the question of improved issuer information. We compare outcomes when the issuer receives one signal,  $y^{i'}$ , about each asset  $i$  to those when it receives two conditionally independent signals,  $y^{i'}$  and  $y^{i''}$ . Both signals satisfy the properties we have imposed in Section 2. Then:

**Proposition 4** (Issuer Information). *Expected profit is greater, but the investor’s expected utility and expected total welfare are lower when the issuer gets  $y^{i'}$ ,  $y^{i''}$  than when it gets only  $y^{i'}$ .*

Since the issuer is rational and can always ignore information, its expected profit is trivially higher if it observes both  $y^{i'}$  and  $y^{i''}$  than if it observes only  $y^{i'}$ . The opposite is true for welfare. In particular, under the interpretation that the issuer’s informational advantage derives from its ability to trade (and hedge) in the professional market, our model says that a more informationally efficient professional market leads to lower welfare in the retail investment market. Intuitively, additional information makes the most extreme possible information the issuer can receive more extreme. Since the issuer chooses an underlying asset with such ex-

treme information, this increases the divergence between the parties' beliefs about the security, lowering welfare.

Next, we consider investor information, focusing on the realistic scenario where the information the investor receives—e.g., from the press, analysts, etc.—is imprecise and inferior to the issuer's information. We suppose that the investor receives directional information  $z^i \in \{z_1^i, \dots, z_{M'}^i\}$  for an infinite number of securities. We assume that the issuer also observes  $z^i$ , and comment on the role of this assumption below. The investor's information is inferior to the issuer's: given  $y^i$ ,  $z^i$  provides no information about the asset ( $f(s_n^i|y^i) = f(s_n^i|y^i, z^i)$  for all  $y^i, z^i$ ).<sup>4</sup> In addition, the investor's information is noisy relative to the issuer's: conditional on any  $y^i$ ,  $z^i$  has full support. Proposition 5, which we view as one of our most important results, identifies the issuer's behavior and the welfare implications in this case:

**Proposition 5** (Investor Information). *The issuer writes the security on an underlying asset about which the investor has information, and  $y^i = y_1, z^i = z_{M'}$ . As compared to when the investor has no information, (i) expected profit is greater, but the investor's expected utility and expected total welfare are lower; (ii) the security is more speculative ( $c_n^i(y_1, z_{M'}) + \underline{c}) / (c_n^i(y_1, \emptyset) + \underline{c})$  is increasing in  $n$ ); and (iii) undersaving is more severe ( $E(u'(c_n^i(y_1, z_{M'}) + \underline{c})|y_1) > E(u'(c_n^i(y_1, \emptyset) + \underline{c})|y_1) > 1$ ).*

Although the information the investor receives moves her beliefs in the right direction on average, given that her information is noisy and inferior there is bound to be an asset for which she receives misleading information. Selecting this asset as the underlying asset allows the issuer to take a bigger bet with the investor, leading to a steeper security, greater profits, and lower investor and total welfare. Furthermore, since the issuer increases the security's payoff in the unlikely high states and decreases it in the likely low states, it exacerbates the investor's undersaving.

Our result that inferior and noisy information lowers welfare implies a kind of discontinuity. If the investor receives the same information as the issuer, welfare is maximized and hence discretely higher than if she receives no information. If the investor receives information that is arbitrarily close in distribution to the issuer's, however, welfare can be discretely lower than

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<sup>4</sup> When  $z^i$  is new information to both parties, we can think of our inferiority assumption as the limit case of a situation where  $z^i$  moves the investor's beliefs much more than the issuer's beliefs.

if she receives no information. As an example, suppose that the issuer’s and investor’s signals have the same range, and the investor receives the issuer’s signal  $y^i$  with probability  $1 - \epsilon$  and a signal drawn uniformly with probability  $\epsilon$ . This satisfies the conditions of our proposition, so that the issuer chooses an underlying asset  $i$  for which it has received signal  $y^i = y_1$  and the investor has received signal  $z^i = y_M$ . Note that if the issuer’s information is precise, so is the investor’s. As a result, the beliefs induced by the signals  $y_1$  and  $y_M$  are very different, leading to an extremely steep security and extremely low welfare. Intuitively, upon receiving the signal  $z^i = y_M$ , the investor thinks that the state  $s^i$  is likely to be high. She realizes that her signal is uninformative with some probability, but believes that the probability is low. Of course, the issuer has chosen precisely the rare underlying asset for which the investor’s signal is uninformative. While this stark example strongly uses our assumptions that there are infinitely many assets and even very precise information has full range—and hence the issuer can always find an asset for which the investor’s information is extremely misleading—the example illustrates that even small amounts of noise in investors’ information can drastically lower welfare.<sup>5</sup>

Proposition 5 has potentially far-reaching positive as well as normative implications. On the positive side, the proposition predicts that structured securities and exotic exchange-traded funds are written on underlying assets about which information is readily available to investors. This prediction is broadly consistent with Henderson and Pearson’s (2011) observation that the vast majority of structured products are issued for underlying stocks that are commonly known. Furthermore, Bergstresser (2008) and Henderson and Pearson (2011) document that issuance is more likely for underlying stocks with high past return and volatility, which researchers (e.g., Barber and Odean, 2008) take as a sign that investors know about these stocks. By the same token, the proposition implies that an issuer is happy to provide information to investors, so long as it is noisy and inferior to its own information. And among investors who are less well-informed than issuers (likely the majority of investors), issuers prefer better-informed investors. In a sense, this implication is a counterexample to a common finding in the behavioral industrial organization literature, that naive consumers are more profitable than

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<sup>5</sup> It is worth noting that there are forms of convergence for which welfare converges to first-best as the investor’s posterior beliefs converge to the issuer’s posterior beliefs. In particular, if *with probability one* the investor’s beliefs about an asset are close to the issuer’s beliefs, then welfare is close to first-best.

sophisticated consumers.

An important normative message of Proposition 5 is that the drastically increased availability of financial information may have made many investors worse off. By the same token, public policies aimed solely at improving investor information—which, even if well-conceived, is bound to leave the majority of investors with information that is noisy and inferior to issuers’ information—are likely to backfire. Nevertheless, given the above considerations, issuers will favor such transparency policies. Finally, the proposition suggests that more sophisticated—in our case, better-informed—investors are worse off than less sophisticated investors. Although the type of sophistication is typically different, in many or most models of behavioral industrial organization sophisticated consumers fare better than naive consumers (Eliaz and Spiegel, 2006; Gabaix and Laibson, 2006; Heidhues and Kőszegi, 2010, for instance).

Since the investor does not understand how the underlying asset and security are selected, she does not understand the above implications. In fact, since she believes that she is an expected-utility maximizer, she views information as useful. As a result, she is willing to expend resources to collect even costly information, exposing herself to the double whammy of paying information-acquisition costs as well as getting a worse security.

While we have assumed that the issuer observes  $z^i$ , in some situations—e.g., when  $z^i$  depends on the investor’s subjective interpretation of a news story—it may not. If the issuer can offer many securities from which an investor selects, however, the unobservability of  $z^i$  does not affect the features of the security the investor buys. For any asset for which investors have information and the issuer has received signal  $y_1$ , the issuer can include in its menu a security that is optimal *assuming* that the investor has received the signal  $z_{M'}$ . Since the securities are upward-sloping and identical, the investor is willing to choose a security for which she has indeed received the most favorable signal  $z_{M'}$ . Furthermore, all other securities look too expensive to her.

## 5 Standardization

In this section, we consider one particular market intervention that typically increases welfare. The intervention we propose is a kind of standardization: restricting the set of underlying

assets on which the issuer can write the security. In particular, we suppose that the social planner chooses one underlying asset in an arbitrary way that is independent of the issuer’s information, and requires that any security be based on that underlying asset. For simplicity, we assume that the issuer has private information, but investors do not receive information. Let the chosen underlying asset be asset  $j$ . Our main proposition identifies a condition under which standardization increases welfare:

**Proposition 6.** *If*

$$D(f(s_n^i|y_1) || f(s_n^i)) > D(f(s_n^i|y_M) || f(s_n^i)), \quad (6)$$

*then standardization increases welfare for any realization of the issuer’s private information:  $W^i(y_1, \emptyset) \leq W^j(y^j, \emptyset)$  for any  $y^j$ , and the inequality is strict unless  $y^j = y_1$ .*

The proposition says that if Condition (6) holds, then whatever is the issuer’s private information, welfare is higher with standardization than without. Intuitively, standardization prevents the issuer from reliably choosing an underlying asset for which its information is most extreme, preventing the parties from taking large welfare-decreasing bets against each other.

To understand the role of Condition (6) in our result, recall that without standardization the issuer chooses an underlying asset for which its signal is extreme, and we have assumed that—as captured in Condition (5)—it prefers an asset with the worst rather than the best possible signal. Just like Condition (5), Condition (6) requires that the “distance” between  $f(s_n^i)$  and  $f(s_n^i|y_1)$  be greater than the distance between  $f(s_n^i)$  and  $f(s_n^i|y_M)$  in the KL divergence sense. The difference is that the order of the distributions is reversed, and because the KL divergence is not symmetric, the two conditions are not equivalent. Nevertheless, since both KL divergences measure the distance between the two distributions, they often rank distances in the same way, and the asymmetry between them can be analytically bounded (Audenaert, 2013, for example). Hence, standardization increases welfare under an arguably weak condition. Furthermore, under this condition the sense in which welfare increases—i.e., that it does so for any signal realization—is strong.

Of course, while standardization increases welfare, it does not achieve first-best, and there is simple policy that does: banning trade in risky securities. This raises the question of why we focus on standardization. The reason is simple: the prescription of banning all trade in

risk is clearly unrealistic and relies on the feature of our model that the only reason to trade risk is speculation. In contrast, in Section 6.2 we argue that standardization is robust to incorporating a non-speculative reason for trading risk into our model.

Standardization not only directly increases welfare, it also modifies the effect of investor information on welfare. Suppose that there are two conditionally independent pieces of information,  $y' \in \{y'_1, \dots, y'_{M'}\}$  and  $y'' \in \{y''_1, \dots, y''_{M''}\}$  about the (now) single underlying asset. Any information the investor receives that is also available to the issuer raises welfare in expectation:

**Proposition 7** (Investor Information Under Standardization). *Giving more information to both parties raises expected social welfare ( $E_{y''|y'}[W((y', y''), y'')] \geq W(y', \emptyset)$ ). In addition, giving information to the investor that the issuer already has also raises expected social welfare ( $E_{y''|y'}[W((y', y''), y'')] \geq E_{y''|y'}[W((y', y''), \emptyset)]$ ).*

Unlike without standardization, the issuer is unable to systematically select an underlying asset about which the investor's information is misleading. Indeed, investor information moves the parties' beliefs regarding the mandated underlying asset closer together on average, mitigating the issuer's incentive to take welfare-decreasing bets against the investor. This insight qualifies a policy implication we have emphasized earlier in an interesting way: while without standardization an information-based policy is prone to backfire, with standardization it is beneficial. In this sense, standardization-oriented and information-oriented policies are complements.

Improved information on the part of the issuer, however, still lowers welfare:

**Proposition 8** (Issuer Information Under Standardization). *Giving more information to the issuer lowers expected total welfare ( $E_{y''|y'}[W((y', y''), \emptyset)] \leq W(y', \emptyset)$ ).*

Intuitively, by the law of iterated expectations, additional information does not change the issuer's beliefs on average. But since the welfare loss from taking bets against the investor is convex, the reduction in welfare when the parties' beliefs move further apart is greater than the increase in welfare when the parties' beliefs move closer together. As a result, average welfare decreases.

## 6 Extensions and Modifications

In this section, we consider various extensions and modifications of our basic model.

### 6.1 Custom-Designed Underlying Assets

Our basic model assumes that an issuer must write the security as a function of a single underlying asset. While this assumption is consistent with the typical security offered to small investors—which is based on a single pre-existing stock, index, or exchange rate—in some markets it may be possible for an issuer to base the security on a new combination of multiple assets. In this section, we briefly consider the welfare implications of such securities.

We consider a modification of our model with no investor information. We assume that the issuer can create a custom index from the underlying assets, and write the security on this index, in the following way. The issuer identifies a sequence of assets  $i_1, i_2, \dots$  and relative weights  $w^{i_1}, w^{i_2}, \dots$  to form an index of the economy

$$S = \lim_{J \rightarrow \infty} \frac{\sum_{j=1}^J w^{i_j} s^{i_j}}{\sum_{j=1}^J w^{i_j}}.$$

The issuer chooses the index after observing its private information, and we require that the above sum converges with probability 1 according to both the issuer's and the investor's beliefs. The issuer can offer any security  $h(S)$  to the investor. To ensure the existence of a solution, we impose that the lowest and highest possible payoffs of the security are  $c_{min}$  and  $c_{max}$ , respectively.<sup>6</sup>

The outcome is very simple to describe in this version of our model:

**Proposition 9** (Optimal Security with Diversification). *The security's period-2 payoff is  $c_{min}$  with probability one, whereas the period-1 price the investor pays corresponds to a belief that she will receive  $c_{max}$  with probability one ( $p = u(c_{max} + \underline{c}) - u(\underline{c})$ ).*

One way for the issuer to sell the lowest possible consumption at the highest possible price—a deal it clearly cannot beat—is the following. The issuer chooses as its index an

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<sup>6</sup> These exogenous bounds—which can be arbitrarily loose—are necessary in our model because of the availability of infinitely many underlying assets and the lack of counterparty risk, capital requirements, or other considerations limiting the parties from taking extreme positions. In a less extreme version with finitely many assets and some costs of taking large bets, such exogenous bounds would be unnecessary. We can think of the previous versions of our model as situations in which these bounds do not bind.

infinite sequence of securities for which it has observed the signal  $y_1$ , and puts equal weights on them. By the law of large numbers, both the issuer and the investor believe that the index has a degenerate distribution. Let their beliefs about the value be  $\bar{S}$  and  $\bar{S}'$ , respectively. Since for each asset in the index the investor's belief first-order stochastically dominates the issuer's belief, we must have  $\bar{S}' > \bar{S}$ . A security that achieves the properties identified in Proposition 9 is  $h(S) = c_{min}$  if  $S < (\bar{S} + \bar{S}')/2$ , and  $h(S) = c_{max}$  if  $S \geq (\bar{S} + \bar{S}')/2$ .

The outcome identified in Proposition 9 has several noteworthy properties. The issuer uses the many available assets to eliminate idiosyncratic risk through indexing. But while diversification is generally thought to benefit an investor and social welfare, here the opposite is the case: the security the investor buys minimizes her welfare and maximizes her undersaving, and if  $c_{min}$  is sufficiently low, it also minimizes social welfare. Intuitively, diversification does have the desired effect of eliminating idiosyncratic risk, but—since the investor does not realize that the index is designed strategically and hence is not representative of the market—this only solidifies the issuer's informational advantage and allows the parties to take huge bets against each other.

The prediction that the issuer can eliminate all perceived risk and induce the most extreme bets relies on our assumption that there are infinitely many idiosyncratic securities. Even with finitely many securities, however, the central mechanism—that indexing lowers perceived risk and hence the willingness to take large positions—is likely to hold.

An equivalent interpretation of the current version of our model is that the investor—rather than ignoring the informational content of the offer of an issuer she knows to be informed—falsely believes that an uninformed party is designing the index, when in fact an informed party is. Under this interpretation, the custom-designed security our model predicts appears to capture the flavor of the custom-tailored CDO's that received scrutiny in relation to the ABACUS scandal. As described in more detail in Davidoff et al. (2011), in 2007 Goldman Sachs created a synthetic CDO based on a basket of mortgage-backed bonds. While the investors were under the impression that the underlying bonds had been selected by an independent third party, in reality the hedge-fund manager John Paulson was also involved—and at the same time was speculating on the default of these bonds. Indeed, ABACUS and other similarly created CDOs performed extremely poorly during the financial crisis. In 2010, the Securities

and Exchange Commission (SEC) accused Goldman Sachs of hiding the role and incentives of Paulson in the deal. According to the SEC, Paulson managed to shift the basket of underlying assets toward mortgages he believed would perform especially badly when house prices decline. Goldman Sachs agreed to pay \$550 million without admitting or denying wrongdoing.

## 6.2 Financial Innovation and Standardization with Aggregate Risk

In this section, we argue that standardization tends to remain welfare-increasing when we incorporate a non-speculative reason for trading risk into our model, and consider the welfare implications of financial innovation in this setting. Following a standard asset-pricing approach (e.g., Cochrane, 2009), we suppose that the issuer's cost of providing a given cash-flow pattern is determined by state prices derived from the utility function of a representative professional investor facing exogenous risky aggregate consumption.<sup>7</sup> This investor has consumption  $e_k$  in state  $k \in \{1, \dots, K\}$  in period 2, and has the concave utility function  $v(\cdot)$  in period 2. There is one underlying asset, which we call the fundamental asset, that is exposed only to the aggregate risk, paying off  $s_k$  in state  $k$ . For simplicity, we assume that neither party has information about the aggregate state. Professional investors do not discount the future, and their marginal utility in period 1 is 1. These assumptions imply that providing a security that pays  $x_1, \dots, x_K$  in states  $1, \dots, K$  costs  $\sum_k f(s_k) v'(e_k) x_k$ .

In addition to the fundamental asset, there are a countable number of assets  $i$  that carry only idiosyncratic risk and satisfy the assumptions we have made previously. We also keep our basic assumptions in all other respects: we assume that the issuer observes private signals about each of the idiosyncratic assets, and then offers a security based on one underlying asset. Again for simplicity, we assume that investors receive no information.

It is easy to see that in the above setting, the first-best security is based on the fundamental asset and has a form  $(c_1, \dots, c_K)$  satisfying

$$u'(c_k + \underline{c}) = v'(e_k)$$

for each  $k$ . The first-best outcome is to trade a security written on the fundamental asset

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<sup>7</sup> The consumption process is exogenous for simplicity. This assumption is appropriate in the limit case in which retail investors are vanishingly small relative to the professional market, so that the presence of the retail market does not affect prices in the professional market.

that allows the investor to take on an optimal amount of aggregate risk given her and the professional investor's preferences.

In an unrestricted market, however, the issuer does not necessarily offer a first-best security. The issuer faces a tradeoff: to optimally respond to variation in state prices, it prefers to write the security on the fundamental asset, but to take advantage of its private information vis a vis the cursed investor, it prefers to use the underlying asset on which it has the most extreme signal. Hence, if its most extreme possible signal on the idiosyncratic assets is sufficiently extreme, it writes the security on an idiosyncratic asset. This introduces two sources of welfare loss: the investor takes on too little of the fundamental risk, and too much of the underlying asset's idiosyncratic risk.

Since it is optimal for the investor to take on some fundamental risk, in this variant of our model banning trade in risky securities does not lead to first-best. Nevertheless, as in our basic model standardization improves welfare under weak conditions. If the policymaker imposes that all securities be written on the fundamental asset, then because the issuer has no private information on the fundamental asset, the first-best results. Even if the issuer has some private information, standardization increases welfare by directing trade toward the fundamental risk. Of course, this standardization is not uninformed in the sense that the policymaker needs to know which asset carries fundamental risk. It seems likely, however, that policymakers have a good idea about aggregate risk factors.

One important caveat regarding our standardization result is in order. While our model assumes that investors' only option is to trade with the issuer, it seems plausible to assume that investors can trade the underlying assets on a competitive financial market. As analyzed in detail by Eyster et al. (2014), if cursed investors neglect the information content of asset prices, then they overestimate the returns they can achieve in idiosyncratic assets. This implies that after standardization, they may prefer to trade in the market for idiosyncratic assets. If this is the case, then banning trade in non-fundamental assets is necessary for standardization to have its intended effect of directing trade toward the fundamental risk.

Finally, we comment on the welfare effect of financial innovation itself, which we think of as expanding the set of tradable securities from just the underlying assets to all derivative securities. On the one hand, there is a role for financial innovation in that it can help the

parties trade fundamental risk in a more optimal way. For instance, if investors like principal protection, it is optimal for the issuer to construct such a security for them. On the other hand, financial innovation may allow the issuer to design a profitable but welfare-decreasing new bet on an idiosyncratic asset. As a result, the net effect of financial innovation is ambiguous.

### 6.3 Social Welfare According to the Investor

While we feel that our interpretation based on cursedness is far better-founded and far more plausible, our model has a formally equivalent restatement in a world of rational agents with heterogeneous priors regarding the informational setting in which they trade. Suppose that the parties have the same beliefs regarding the unconditional distribution of the assets' payoffs, but disagree on how the signals are generated. Specifically, the issuer believes that its signals  $y^i$  are generated as we have assumed above, but the investor believes that the  $y^i$  are uninformative, with the parties' beliefs regarding the investor's signals being unchanged. This framework generates the same securities as our model. But in the heterogenous-priors restatement of our model, it is arbitrary to evaluate welfare according to the issuer's beliefs, so we briefly discuss how our basic welfare results may change if welfare is evaluated according to the investor's beliefs.

To begin, it is easy to show that our undersaving result does not survive in this version of the model. Equation (3) implies that when evaluated according to the investor's beliefs,  $E[u'(c_n^i + \underline{c})] = \sum_n f(s_n^i)(f(s_n^i|y^i)/f(s_n^i)) = \sum_n f(s_n^i|y^i) = 1$ , so that the investor's savings level is just right.

The key mechanism behind all of our other main results, however, remains in force in the current version of the model. Our result that information to either party lowers social welfare (Propositions 4 and 5) relies on the observation that either type of information leads the parties to trade a more speculative security. Furthermore, our result that standardization raises welfare (Proposition 6) relies on the observation that it leads the parties to trade a less speculative security. While we have not attempted a formal generalization, these results are likely extend under many conditions for a simple reason: since a more speculative security tends to move consumption away from optimal, it tends to decrease welfare according to both

parties' beliefs— although the parties disagree as to who bears the decrease in welfare.<sup>8</sup>

## 6.4 Competition Between Issuers and Access to Derivatives Market

We study what happens when an investor has access to a competitive financial market, either because she receives offers from competitive issuers or because she can design any payoff structure for herself at the same cost as (but without the help of) an issuer. The results show that the main determinant of total welfare is not the presence or market power of issuers, but the ability of either party to tailor investment positions precisely in the way the investor wants.

We modify the environment of Section 4—in which an issuer has private information  $y^i$  on each underlying asset  $i$  and writes the security on one underlying asset, and the investor has information  $z^i$  on an infinite number of assets  $i$ —by positing that *two* issuers simultaneously offer securities to investors. The two issuers receive identical signals.

In this situation, we can think of an issuer's problem in two parts. First, the issuer solves for the optimal security given the security's level of perceived expected utility. Second, it chooses the perceived expected utility. Since the first part is independent of the presence of the other firm, it is identical to the issuer's problem in our basic, single-firm model. As a result, firms choose the same security. The second part of the problem, which determines the security's price in equilibrium, depends on competition. Because firms face a variant of Bertrand competition, in equilibrium price equals expected cost.

Given the above considerations, in equilibrium both issuers choose an underlying asset  $i$  satisfying  $y^i = y_1$ ,  $z^i = z_{M'}$ , and offer the security  $c_n^i(y_1, z_{M'})$  for the competitive price

$$p = \sum_n f(s_n^i | y^i) \left( \frac{f(s_n^i | z^i)}{f(s_n^i | y^i)} - \underline{c} \right) = 1 - \underline{c}.$$

Since investors are buying the same security as in Section 3, total welfare is unaffected by competition. Competition transfers the firms' profits to investors, but investors are still undersaving and holding a suboptimal amount of risk.

To sharpen our intuition regarding what drives low welfare, we consider another competitive market: one in which the investor can design any payoff structure for herself at the same cost as the issuer. We assume that the investor has access to a professional derivatives market,

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<sup>8</sup> Davila (2015) makes the related point that in endowment economies with heterogeneous priors, taxing bets might be welfare-improving regardless of whose beliefs are correct.

where  $f(s_n^i|y^i)$  is the price of a security providing a unit of consumption in state  $s_n^i$ . To make the security comparable to that of issuer-designed securities, we continue to impose that the security the investor puts together must be written on a single underlying asset. Hence, an investor with information  $z^i$  solves

$$\max_{i, c_n^i} \sum_n [f(s_n^i|z^i) \ln(c_n^i + \underline{c}) - f(s_n^i|y^i) c_n^i].$$

This maximization problem is equivalent to that of the issuer when it designs the security (Equation (2) augmented by the choice of  $i$ ), so it results in the same payoff pattern. Intuitively, the investor maximizes her perceived expected utility given her information, net of the security's market price. But since the investor's perceived expected utility corresponds to her willingness to pay for the product and the market price corresponds to an issuer's cost, the issuer's objective when it designs the security is exactly the same.<sup>9</sup> The only difference is that when the investor designs the security herself, she obtains the same payoff pattern at cost.

## 6.5 Competition vs. Monopoly with Endogenous Information Acquisition

One of the main results of our paper is that (noisy and inferior) information lowers investor welfare. As we have noted, an immediate implication is that investors are willing to expend resources to collect information that makes them worse off even gross of the information-acquisition costs. In this section, we compare the incentives for welfare-decreasing information acquisition with and without competition, and find that they are higher under competition. Hence, competition is not only ineffective at increasing welfare, it actually lowers welfare by encouraging harmful information search.

We begin by analyzing the more difficult case, monopoly. When investors may or may not acquire information, the monopolist optimally screens informed and uninformed investors. We extend and slightly modify our basic model to make this screening problem tractable. We suppose that—having observed its private information—the issuer offers a menu of securities. Investors receive information  $z^i$  on an infinite number of underlying assets, but there are also infinitely many assets for which they do not receive information. The issuer knows the assets

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<sup>9</sup> Some considerations outside our model may qualify this result. For instance, it may be more difficult for an investor to design a perceived-optimal security than to evaluate a specific security on offer, so that the investor may not arrive at the same solution as the issuer.

for which investors have information, but does not know the realized signals  $z^i$  when designing its securities. After observing the menu, investors decide whether to acquire the signals  $z^i$ , with investors acquiring either all or none of the available signals. The cost of information acquisition is heterogeneous across investors, with cumulative distribution function  $G(\cdot)$  and probability density function  $g(\cdot)$ . We assume that the support of  $G(\cdot)$  is  $[0, X]$ , where  $X$  is sufficiently large for the set of investors who acquire information to be interior, and  $x + G(x)/g(x)$  is increasing in  $x$ . After the relevant subset of investors has acquired information, both informed and uninformed investors either choose not to participate, or choose one security from the issuer's menu.

As a first step in our argument, suppose for a moment that all investors are informed, and that the issuer wants to give them perceived surplus  $x \geq 0$ . Then, as we have argued in Section 4, the issuer achieves the same profit as when it observes the signals  $z^i$ : for any asset for which investors have information and the issuer has received signal  $y_1$ , the issuer can include in its menu a security that is optimal *assuming* that the investor has received the signal  $z_{M'}$ , and sell them at the same price that leaves a consumer with signal  $z_{M'}$  with perceived surplus  $x$ . Since the securities are increasing and identical, an informed investor chooses a security for which she has received signal  $z_{M'}$ .

Now suppose that there are also uninformed investors. For these investors, the monopolist can include in its menu an optimal security written on an underlying asset for which it has observed  $y_1$  but about which no investor has information, pricing the security to leave investors with zero perceived surplus. Given that informed investors get non-negative perceived surplus from the security designed for them and zero perceived surplus from this one, they do not want to take this security. Assume for a moment that uninformed investors in turn do not want to take a security designed for informed investors; we argue below that this is the case.

We are now ready to consider an investor's information-acquisition problem when facing the above menu. The investor knows that if she remains uninformed, she receives a perceived surplus of zero. Furthermore, she realizes that if she becomes informed, she will get signal  $z_{M'}$  for some security, so that her perceived surplus will be  $x$ . Intuitively, the investor thinks that by searching for information, she will be able to figure out which of the expensive-looking securities are a good deal. This determines her incentive to acquire information.

In designing its securities, the firm chooses  $x$  optimally given the following tradeoff. On the one hand, increasing  $x$  leads more investors to acquire information and hence to choose the firm's more profitable product, the one aimed at informed investors. On the other hand, increasing  $x$  lowers the firm's margin on its more profitable product. This tradeoff makes clear that the monopolist does not make  $x$  so high that the security aimed at informed investors becomes less profitable. Because these securities are more expensive and from the point of view of uninformed investors too steep, they never want to take these securities.

Based on the above considerations, Proposition 10 identifies the features of the market outcome under monopoly.

**Proposition 10** (Information Acquisition Under Monopoly). *In equilibrium, (i) informed investors buy the security  $c_n^i(y_1, z_{M'})$  written on an underlying asset  $i$  for which  $y^i = y_1$  and investors have information  $z^i = z_{M'}$ ; and (ii) uninformed investors buy the security  $c_n(y_1, \emptyset)$  written on an underlying asset  $i$  for which  $y^i = y_1$ . The fraction of investors who become informed is  $G(x)$  defined by*

$$D(f(s_n^i|z_{M'})||f(s_n^i|y_1)) - D(f(s_n^i)||f(s_n^i|y_1)) = x + \frac{G(x)}{g(x)}. \quad (7)$$

We now consider the competitive economy, in which investors can design any security for themselves at the same cost as the issuer. Our analysis above implies that if informed the investor puts together the security  $c_n^i(y_1, z_{M'})$  written on an asset  $i$  with  $y^i = y_1, z^i = z_{M'}$ , and if uninformed she puts together the security  $c_n^i(y_1, \emptyset)$  written on an asset  $i$  with  $y^i = y_1$ . The cost of both of these securities is  $1 - \underline{c}$ . Hence, the incentive to acquire information is the difference in the perceived expected utilities these securities offer to the two types of consumers:

$$D(f(s_n^i|z_{M'})||f(s_n^i|y_1)) - D(f(s_n^i)||f(s_n^i|y_1)) = x + \frac{G(x)}{g(x)},$$

where the last equality is implied by Equation (7). Thus, the fraction of consumers who acquire information is  $G\left(x + \frac{G(x)}{g(x)}\right) > G(x)$ , so that:

**Proposition 11** (Competition Increases Information Acquisition). *The fraction of investors who acquire information is greater under competition than under monopoly.*

Since the total welfare generated by a security that an informed investor chooses is lower than the total welfare generated by a security that an uninformed investor chooses, competi-

tion lowers welfare. Intuitively, competition generates a greater incentive to acquire welfare-decreasing information by leaving all of the perceived gain from better information in the investor's hands. To profit from consumers' trading on misleading information, a monopolist takes away some of the perceived gain, thereby also lowering the incentive to acquire information in the first place.

Combining our result that an increase in competition leads to an increase in the number of investors acquiring information with our earlier observation that the securities issuers offer to more informed investors are steeper leads to a potentially testable prediction of our model: that an increase in competition leads parties to trade more speculative securities. Unfortunately, we are not aware of empirical work on this prediction.<sup>10</sup>

## 7 Related Literature

Our paper is related to the literature on financial innovation as well as that on contracting with boundedly rational agents. To our knowledge, ours is the first paper to analyze the welfare properties of optimally designed securities when investors underestimate the informational content of issuers' actions. We are also not aware of previous work pointing out that an optimal security induces undersaving for a biased (but time-consistent) investor, that inferior information lowers total welfare, and that standardization typically increases welfare.

The literature on rational security design studies the optimal way for a firm to raise capital in the presence of adverse selection (Nachman and Noe, 1994; DeMarzo and Duffie, 1999; Yang, 2013) or moral hazard (Innes, 1990; Hebert, 2015). While these considerations are fundamental in the corporate context, it is plausible to suppose that they are less central in the retail finance context. A retail investor likely finds it difficult to deduce the issuer's private information or incentives from the contract she is offered, or does not even think about these questions. As a result, the issuer is less worried about the investor's inference, radically changing the motives

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<sup>10</sup> A comment on the role of our assumption that a monopolist can offer a large menu of securities may be useful. This ensures that when an investor considers whether to get information, she knows that she will find a security written on an underlying asset for which she has received signal  $z_{M'}$ . Although we have not formally considered such variants of the model, it seems that if there are fewer securities in the marketplace, then an investor sees less of a chance that she will find a good deal, lowering her incentive to acquire information. To the extent that competition leads to more securities being offered, therefore, this provides an additional reason that competition encourages harmful information acquisition.

behind security design. By assuming that investors are fully cursed, we focus on analyzing the new considerations that arise.<sup>11</sup>

Of the various views on financial innovation, our work is most related to two strands of the literature arguing that financial innovation facilitates bets in environments where the no-trade theorems do not hold.<sup>12</sup> First, there is a group of papers considering the role of financial innovation with heterogeneous priors. Simsek (2014) establishes that introducing new markets by financial innovation increases the volatility of consumption by introducing new ways of betting. Shen et al. (2014) argue that financial innovation helps reduce the cost of betting by minimizing the associated collateral requirement. Fostel and Geanakoplos (2012) focus on the interaction between financial innovation and endogenous leverage, showing that the sequential introduction of new financial products can result in boom-and-bust cycles.

Second, there is a group of papers modeling situations in which individuals are willing to take bets due to various cognitive biases. Gennaioli et al. (2012) study financial innovation when investors are extremely risk-averse but neglect some low-probability risks, leading to the creation of seemingly safe securities that pay less in the neglected state. In contrast, we show that cursedness in general implies the creation of steep, speculative securities. Related to this observation, multiple researchers (e.g. Adrian and Westerfield, 2009; Landier and Thesmar, 2009; de la Rosa, 2011; Gervais et al., 2011) have shown that a principal often gives high-powered incentives to overconfident agents, effectively motivating them with dreams that are unlikely to materialize. It would be interesting to study the questions we raise in this paper in the context of overconfidence. We work with cursedness largely for epistemic reasons: it seems realistic to assume that retail investors buy structured assets not because they think they are better than the professionals they are trading with, but because they do not think through the incentives of the other side.<sup>13,14</sup>

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<sup>11</sup> A telling sign of the distance between the rational approach and ours is that in Hebert (2015) the optimal security—debt—minimizes relative entropy, whereas in our setting the optimal security maximizes relative entropy.

<sup>12</sup> More classical and less related contributions include Allen and Gale (1994), who argues that new securities help hedging in an incomplete market setting, and Gorton and Pennacchi (1990) and Dang et al. (2012), who show that financial innovation can increase the liquidity of assets by decreasing their sensitivity to private information.

<sup>13</sup> See Eyster and Rabin (2005) for some comparisons between cursedness and overconfidence.

<sup>14</sup> Beyond research on overconfidence, our paper is broadly related to the growing literature on market competition and contracting with naive consumers. See Spiegel (2011) and Kőszegi (2014) for reviews.

The closest paper to ours is Eyster et al. (2014), which considers the impact of cursed traders in an otherwise standard asymmetric-information rational-expectations-equilibrium model with a fixed set of securities. The paper’s main insight is that cursedness can explain the puzzlingly high volume of trade in financial assets. Eyster, Rabin, and Vayanos also consider the effect of investor information. A cursed trader with more precise information has a better estimate of the fundamental value of the asset, but takes riskier positions against rational traders. When this second effect dominates, more precise information makes cursed traders worse off. Due to the issuer’s ability to optimize the security, in our setting information *always* lowers the investor’s utility, and in addition always lowers total social welfare as well.

## 8 Conclusion

Our analysis raises several questions regarding the role of cursedness in financial markets. In our model, the shape of an optimal security is determined only by the parties’ information and preferences, but in reality other considerations—such as the ease of writing or marketing contracts or hedging a security in the professional market—also play a role. The exact features of real-life securities, such as their shape or time horizon, are likely also influenced by these additional considerations. Furthermore, while our model assumes exogenously that investors are fully cursed, many or most investors may be only partially cursed, and their degree of cursedness may even depend on market conditions. For instance, if a security is too blatant in taking advantage of cursedness—such as when it is a bet on the flip of a coin flip the issuer supplies—some investors might be clued in that they should think about the other side’s information. In this sense, there appears to be a kind of “plausibility” constraint on these securities—that there should be a plausible reason for the security to make a better return than alternatives. What such plausibility constraint precisely entails is a fruitful topic for future research. Finally, the observation that investors are likely to be heterogenous in their cursedness raises the possibility that issuers screen investors along this dimension.

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## Proofs

**Proof of Proposition 1.** Suppose there is some underlying asset  $i$  with information  $y^i$  for which the issuer does not offer the first-best, but instead offers  $c^i$ . Let  $Y$  be the set of  $y^i$  for which the issuer offers  $c^i$ . Then the maximum price at which the rational investor is willing to buy the security is

$$p = E [u(c_n^i + \underline{c}) | y^i \in Y] - u(\underline{c})$$

The expected cost of the issuer is

$$\begin{aligned} E [c_n^i | y^i] &= \sum_n f(s_n^i | y^i) c_n^i = \sum_n \frac{f(s_n^i, y^i)}{f(y^i)} c_n^i = \frac{\sum_{y^i \in Y} f(y^i) \sum_n \frac{f(s_n^i, y^i)}{f(y^i)} c_n^i}{f(y^i \in Y)} = \\ &= \sum_n \frac{f(s_n^i | y^i \in Y)}{f(y^i \in Y)} c_n^i = E [c_n^i | y^i \in Y] \end{aligned}$$

Then issuer maximizes expected profit (taking  $i$  as given)

$$\begin{aligned} \max_{\underline{c}} p - E [c_n^i | y^i] &= E [u(c_n^i + \underline{c}) | y^i \in Y] - u(\underline{c}) - E [c_n^i | y^i \in Y] = \\ &= \sum_n f(s_n^i | y^i \in Y) [u(c_n^i + \underline{c}) - u(\underline{c}) - c_n^i] \end{aligned}$$

The first order condition yields the first-best contract

$$u'(c_n^i + \underline{c}) = 1$$

This means that conditional on  $Y$ ,  $c^i$  is not profit-maximizing. Hence, there is  $y^i \in Y$  for which  $c^i$  is not profit-maximizing. Switching to first-best on that  $y^i$  increases expected profit, as willingness to pay for first-best does not depend on investor's belief.  $\square$

**Proof of Proposition 2** Using the first order condition of the issuer's problem (Equation (3)):

$$\begin{aligned} \frac{1}{u'(c_n + \underline{c})} &= \frac{f(s_n^i)}{f(s_n^i | y^i)} \\ E \left[ \frac{1}{u'(c_n + \underline{c})} \middle| y^i \right] &= \sum_n f(s_n^i | y^i) \frac{f(s_n^i)}{f(s_n^i | y^i)} = 1 \end{aligned}$$

By Jensen's inequality:

$$E [u'(c_n + \underline{c}) | y^i] > \frac{1}{E \left[ \frac{1}{u'(c_n + \underline{c})} \middle| y^i \right]} = 1$$

$\square$

**Proof of Proposition 3.** Given the underlying asset  $i$ , we denote the issuer's expected profit by  $\Pi^i$ , the investor's expected utility by  $U^i$  implying that

$$\begin{aligned} \Pi^i(y^i, \emptyset) &= D(f(s_n^i) || f(s_n^i | y^i)) - 1 + \underline{c} - u(\underline{c}) \\ U^i(y^i, \emptyset) &= - (D(f(s_n^i | y^i) || f(s_n^i)) + D(f(s_n^i) || f(s_n^i | y^i))) + u(\underline{c}) \end{aligned}$$

hence,  $W^i(y^i, \emptyset) = \Pi^i(y^i, \emptyset) + U^i(y^i, \emptyset)$  as defined.

Take  $y, y' \in \{y_1, \dots, y_M\}$  such that  $y' > y$  and let  $y^i = y$  and  $y^j = y'$ . Then

$$\begin{aligned}\Pi(y, \emptyset) &= \sum_n f(s_n^i) \ln \left( \frac{f(s_n^i)}{f(s_n^i|y)} \right) - 1 - u(\underline{c}) + \underline{c} \\ \Pi(y', \emptyset) &= \sum_n f(s_n^j) \ln \left( \frac{f(s_n^j)}{f(s_n^j|y')} \right) - 1 - u(\underline{c}) + \underline{c}\end{aligned}$$

By symmetry  $f(s_n^i) = f(s_n^j)$  therefore

$$\Pi(y', \emptyset) - \Pi(y, \emptyset) = \sum_n f(s_n^i) \ln \left( \frac{f(s_n^i|y)}{f(s_n^j|y')} \right)$$

Suppose  $y$  and  $y'$  are both good news. Then

$$0 < \sum_n f(s_n^i|y) \ln \left( \frac{f(s_n^i|y)}{f(s_n^j|y')} \right) \leq \sum_n f(s_n^i) \ln \left( \frac{f(s_n^i|y)}{f(s_n^j|y')} \right) = \Pi(y', \emptyset) - \Pi(y, \emptyset)$$

The first inequality follows from the fact that the KL divergence of  $f(s_n^i|y)$  from  $f(s_n^j|y')$  is strictly positive because there exists some  $n$  such that  $f(s_n^i|y) \neq f(s_n^j|y')$ . The second inequality follows from the nature of information  $y$ . Given that  $y$  is directional and good news,  $f(s_n^i|y)$  satisfies the monotone likelihood ratio property with respect to  $f(s_n)$ . Therefore  $f(s_n^i|y)$  first-order stochastically dominates  $f(s_n^i)$  and  $\ln[f(s_n^i|y)/f(s_n^j|y')]$  is strictly decreasing in  $n$ .

This holds for all pairs of good news  $y, y'$  which implies that among good news the issuer's optimal choice is the extreme one ( $y^i = y_M$ ). Using the same line of arguments it can be shown that among bad news the optimal choice is again the extreme one ( $y^i = y_1$ ). Therefore the optimal choice is either  $y^i = y_1$  or  $y^i = y_M$ .

**Proof of Proposition 4.** Since the issuer is rational and can always ignore information, its expected profit is trivially higher if it observes both  $y^{i'}$  and  $y^{i''}$  than if it observes only  $y^{i'}$ .

In line with Proposition 3 the issuer writes the security on underlying securities with extreme information. Also

$$D(f(s_n^i) || f(s_n^i|y', y'')) = \sum_n f(s_n^i) \ln \frac{f(s_n^i)}{f(s_n^i|y')} \frac{f(s_n^i|y')}{f(s_n^i|y', y'')} = D(f(s_n^i) || f(s_n^i|y')) + D(f(s_n^i) || f(s_n^i|y''))$$

where we used that

$$\frac{f(s_n^i|y')}{f(s_n^i|y', y'')} = \frac{f(y'|s_n^i)f(s_n^i)/f(y')}{f(y'|s_n^i, y'')f(s_n^i|y'')/f(y'|y'')} = \frac{f(s_n^i)}{f(s_n^i|y'')} \quad (\text{A.1})$$

by Bayes-rule and because  $f(y'|s_n^i) = f(y'|s_n^i, y'')$  and  $f(y') = f(y'|y'')$  as the two signals are conditionally independent.

Therefore, (5) with two idiosyncratic pieces of information implies that

$$\begin{aligned} D(f(s_n^i) || f(s_n^i|y_1, y_1)) &= 2D(f(s_n^i) || f(s_n^i|y_1)) > \\ &> 2D(f(s_n^i) || f(s_n^i|y_M)) = D(f(s_n^i) || f(s_n^i|y_M, y_M)). \end{aligned}$$

Hence, the issuer chooses an underlying asset  $i$  for which both pieces of signals are minimal.

Note also, that A.1 also implies that for  $(y' = y_1, y'' = y_1)$ ,  $\frac{f(s_n^i|y')}{f(s_n^i|y', y'')}$  is increasing, that is,  $(y' = y_1, y'' = y_1)$  is worse news than  $(y' = y_1)$ . Therefore, the following chain proves that statement for expected welfare:

$$\begin{aligned} W^i(y_1, y_1, \emptyset) - W^i(y_1, \emptyset) &= \sum_n f(s_n^i|y_1, y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1, y_1)} - \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} \\ &= \sum_n f(s_n^i|y_1, y_1) \left[ \ln \frac{f(s_n^i|y_1)}{f(s_n^i|y_1, y_1)} + \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} \right] - \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} \\ &= \sum_n f(s_n^i|y_1, y_1) \ln \frac{f(s_n^i|y_1)}{f(s_n^i|y_1, y_1)} + \sum_n f(s_n^i|y_1, y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} - \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} < 0. \end{aligned}$$

Here we used that the first term is the negative of a relative entropy and the third term is larger than the second term as  $f(s_n^i|y_1)$  first order stochastically dominates  $f(s_n^i|y_1, y_1)$  and  $f(s_n^i)/f(s_n^i|y_1)$  is increasing.

Finally, expected total welfare is the sum of expected profit and expected investor total utility. If the issuer observes both  $y^{i'}$  and  $y^{i''}$  then expected profit is greater and expected total welfare is lower than if it observes only  $y^{i'}$ . Therefore expected investor total utility is also lower with two idiosyncratic pieces of information.  $\square$

### Proof of Proposition 5.

Just as before, for any underlying with or without investor information the first order condition of the issuer implies that the optimal security will have the form of  $c_n^i(y^i, \cdot)$ . Therefore, if the issuer writes a security on an asset about which the investor receives information then

the profit function changes only to the extent that they will depend on  $f(s_n^i|z^i)$  instead of  $f(s_n^i)$ .

First note that if the investor receives information for the chosen underlying, the issuer will choose either  $y^i = y_1$  or  $y^i = y_M$  for all  $z^i$ . The proof of this claim is the same as the proof of Proposition 3 with the modified profit function. We also know that if the issuer chooses  $y^i = y_1$  for a given  $z^i = z$  then  $z$  is better news than  $y_1$  because otherwise  $y^j = y_M, z^j = z$  would be a better choice.

The issuer can effectively choose an underlying security with  $y^i = y_1$  and any  $z^i$  as we assumed that conditional on any  $y^i, z^i$  has full support. Now we show that among those with investor information and  $y = y_1$ , the one with  $z^i = z_{M'}$  dominates the others.

$$\begin{aligned} \Pi^i(y_1, z_{M'}) - \Pi^j(y_1, z) &= \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|y_1)} - \sum_n f(s_n^j|z) \ln \frac{f(s_n^j|z)}{f(s_n^j|y_1)} = \\ &= \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|z)} + \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z)}{f(s_n^i|y_1)} - \sum_n f(s_n^j|z) \ln \frac{f(s_n^j|z)}{f(s_n^j|y_1)} \end{aligned}$$

By symmetry this is equivalent to

$$\sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|z)} + \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z)}{f(s_n^i|y_1)} - \sum_n f(s_n^i|z) \ln \frac{f(s_n^i|z)}{f(s_n^i|y_1)} > 0$$

Here the first term is positive because it is a relative entropy. The second term is larger than the third one because  $f(s_n^i|z)/f(s_n^i|y_1)$  is increasing (as  $z$  is better news than  $y_1$ ) and  $f(s_n^i|z_{M'})$  first order stochastically dominates  $f(s_n^i|z)$ .

An analogous argument proves that securities written on underlyings with investor information and  $y = y_M$ , the one with  $z^i = z_1$  dominates the others which concludes the proof of the claim that the issuer writes the security on an asset  $i$  with either signals  $y^i = y_1, z^i = z_{M'}$  or signals  $y^i = y_M, z^i = z_1$ .

Recall that analogously to (5), we maintain the assumption that the issuer chooses an asset for which it has received the worst information, that is, the optimal security is written on asset with  $y^i = y_1$  and  $z^i = z_{M'}$ . Therefore, to prove claims (i)-(iii) in the Proposition, we only have to compare this security with the optimal security written on an underlying without public information.

For (i), note that

$$\begin{aligned}\Pi^j(y_1, \emptyset) - \Pi^i(y_1, z_{M'}) &= \sum_n f(s_n^j) \ln \frac{f(s_n^j)}{f(s_n^j|y_1)} - \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|y_1)} = \\ &= \sum_n f(s_n^j) \ln \frac{f(s_n^j)}{f(s_n^j|y_1)} - \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} + \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})}.\end{aligned}$$

By symmetry this is equivalent to

$$\sum_n f(s_n^i) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} - \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} + \sum_n f(s_n^i|z_{M'}) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})} < 0$$

Here the last term is negative as it is negative of relative entropy, and the first term is smaller than the second, because  $f(s_n^i|z_{M'})$  first order stochastically dominates  $f(s_n^i)$  and  $\frac{f(s_n^i)}{f(s_n^i|y_1)}$  is monotonically increasing. For welfare, we have

$$\begin{aligned}W^j(y_1, z^j = \emptyset) - W^i(y_1, z_{M'}) &= \\ &= \sum_n f(s_n^j|y_1) \ln \frac{f(s_n^j)}{f(s_n^j|y_1)} - \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|y_1)} = \\ &= \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} - \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i|z_{M'})}{f(s_n^i|y_1)} = \\ &= \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})} = \\ &= \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})} - \sum_n f(s_n^i) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})} + \sum_n f(s_n^i) \ln \frac{f(s_n^i)}{f(s_n^i|z_{M'})} > 0.\end{aligned}$$

Note that  $f(s_n^i)/f(s_n^i|z_{M'})$  is decreasing and  $f(s_n^i)$  first order stochastically dominates  $f(s_n^i|y_1)$  which implies that the first term is larger than the second one. Also, the third term is positive because it is a relative entropy.

Expected total welfare is the sum of expected profit and expected investor utility. If investors have information then expected profit is greater and expected total welfare is lower than if they do not. Therefore investor utility is also lower with investor information.

(ii) If  $y^i = y_1$ ,  $z^i = z_{M'}$  and  $y^j = y_1$  then

$$\frac{c_n(y^i, z^i) + \underline{c}}{c_n(y^j, \emptyset) + \underline{c}} = \frac{c_n(y_1, z_{M'}) + \underline{c}}{c_n(y_1, \emptyset) + \underline{c}} = \frac{f(s_n^i|z_{M'})}{f(s_n^i)}$$

This is increasing because information is directional and  $z_{M'}$  is good news.

(iii) We know from Proposition 2 that the second inequality is satisfied. Also,

$$\begin{aligned}
E[u'(c_n^i(y_1, \emptyset) + \underline{c})|y^i = y_1] &= \sum_n f(s_n^i|y_1) \frac{f(s_n^i|y_1)}{f(s_n^i)} = \\
&= \sum_n f(s_n^i|z_{M'}) \frac{f(s_n^i|y_1)}{f(s_n^i|z_{M'})} \frac{f(s_n^i|y_1)}{f(s_n^i)} < \\
&< \sum_n f(s_n^i) \frac{f(s_n^i|y_1)}{f(s_n^i|z_{M'})} \frac{f(s_n^i|y_1)}{f(s_n^i)} = \\
&= \sum_n f(s_n^i|y_1) \frac{f(s_n^i|y_1)}{f(s_n^i|z_{M'})} = E[u'(c_n^i(y_1, z_{M'}) + \underline{c})|y^i = y_1]
\end{aligned}$$

The inequality follows from that  $f(s_n^i|y_1)/f(s_n^i)$  and  $f(s_n^i|y_1)/f(s_n^i|z_{M'})$  are both positive and decreasing and  $f(s_n^i|z_{M'})$  first order stochastically dominates  $f(s_n^i)$ .  $\square$

**Proof of Proposition 6.** Take any  $y' \in \{y_2, \dots, y_M\}$ . Suppose  $y'$  is bad news.

$$\begin{aligned}
W^i(y_1, \emptyset) - W^j(y', \emptyset) &= \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^i)}{f(s_n^i|y_1)} - \sum_n f(s_n^j|y') \ln \frac{f(s_n^j)}{f(s_n^j|y')} \\
&= \sum_n f(s_n^i|y_1) \left[ \ln \frac{f(s_n^j|y')}{f(s_n^i|y_1)} + \ln \frac{f(s_n^j)}{f(s_n^j|y')} \right] - \sum_n f(s_n^j|y') \ln \frac{f(s_n^j)}{f(s_n^j|y')} \\
&= \sum_n f(s_n^i|y_1) \ln \frac{f(s_n^j|y')}{f(s_n^i|y_1)} + \sum_n f(s_n^i|y_1) \ln \frac{f(s_n)}{f(s_n^j|y')} - \sum_n f(s_n^j|y') \ln \frac{f(s_n)}{f(s_n^j|y')} < 0
\end{aligned}$$

where we used that  $f(s_n^i) = f(s_n^j)$  by symmetry. Note that the first term is strictly negative because it is the negative of a relative entropy. We also know that the third term is larger or equal than the second term because  $f(s_n)/f(s_n^j|y')$  is strictly increasing and  $f(s_n^j|y')$  first-order stochastically dominates  $f(s_n^i|y_1)$ .

Now suppose that  $y'' \in \{y_2, \dots, y_M\}$  is good news and  $y'' = y_M$ . From (6), we know that

$$W^i(y_1, \emptyset) - W^k(y_M, \emptyset) = D\left(f\left(s_n^k|y_M\right) | f(s_n)\right) - D\left(f\left(s_n^i|y_1\right) | f(s_n)\right) < 0.$$

If  $y''$  is still good news but  $y'' \neq y_M$  then as before

$$\begin{aligned}
W^k(y_M, \emptyset) - W^l(y'', \emptyset) &= \sum_n f(s_n^k|y_M) \ln \frac{f(s_n)}{f(s_n^k|y_M)} - \sum_n f(s_n^l|y'') \ln \frac{f(s_n)}{f(s_n^l|y'')} \\
&= \sum_n f(s_n^k|y_M) \left[ \ln \frac{f(s_n^l|y'')}{f(s_n^k|y_M)} + \ln \frac{f(s_n)}{f(s_n^l|y'')} \right] - \sum_n f(s_n^l|y'') \ln \frac{f(s_n)}{f(s_n^l|y'')} \\
&= \sum_n f(s_n^k|y_M) \ln \frac{f(s_n^l|y'')}{f(s_n^k|y_M)} + \sum_n f(s_n^k|y_M) \ln \frac{f(s_n)}{f(s_n^l|y'')} - \sum_n f(s_n^l|y'') \ln \frac{f(s_n)}{f(s_n^l|y'')} < 0
\end{aligned}$$

because the first term is the negative of a relative entropy and the third term is larger or equal than the second term because  $f(s_n)/f(s_n^l|y'')$  is strictly decreasing (as  $y''$  is good news) and  $f(s_n^k|y_M)$  first-order stochastically dominates  $f(s_n^l|y'')$  (as  $y_M$  is the best news).

Therefore, we have

$$\begin{aligned} W^i(y_1, \emptyset) &< W^j(y', \emptyset) \\ W^i(y_1, \emptyset) &< W^k(y_M, \emptyset) < W^l(y'', \emptyset) \end{aligned}$$

concluding the proof.  $\square$

**Proof of Propositions 7 and 8.** For the first claim of Proposition 7

$$E_{y''|y'}[W((y', y''), y'')] \geq W(y', \emptyset) \tag{A.2}$$

recall that the definition of conditional relative entropy between  $h(u|v)$  and  $g(u|v)$  is

$$\sum_v h(v) \sum_u h(u|v) \ln \frac{h(u|v)}{g(u|v)}.$$

Thus, we can write

$$\begin{aligned} E_{y''|y'}[W((y', y''), y'')] &= \\ &= - \sum_{y''} f(y''|y') \sum_{s_n} f(s_n|y', y'') \ln \frac{f(s_n|y', y'')}{f(s_n|y'')} - 1 + \underline{c} = \\ &= - D(f(s_n|y', y'')||f(s_n|y'')) - 1 + \underline{c}. \end{aligned}$$

Therefore, we have to show only that  $D(f(s_n|y', y'')||f(s_n|y'')) \leq D(f(s_n|y')||f(s_n))$ . Also, the chain-rule of relative entropy (Cover and Thomas, Theorem 2.5.3) implies that

$$D(f(s_n|y', y'')||f(s_n|y'')) \leq D(f(s_n, y''|y')||f(s_n, y''))$$

which is equivalent to our claim as

$$\begin{aligned}
D(f(s_n, y''|y')||f(s_n, y'')) &= \sum_{s_n, y''} f(s_n, y''|y') \ln \left( \frac{f(s_n, y''|y')}{f(s_n, y'')} \right) \\
&= \sum_{s_n, y''} f(s_n, y''|y') \ln \left( \frac{f(s_n|y')f(y''|s_n, y')}{f(s_n)f(y''|s_n)} \right) \\
&= \sum_{s_n, y''} f(s_n, y''|y') \ln \left( \frac{f(s_n|y')}{f(s_n)} \right) \\
&= \sum_{s_n} f(s_n|y') \ln \left( \frac{f(s_n|y')}{f(s_n)} \right) \\
&= D(f(s_n|y')||f(s_n)).
\end{aligned}$$

For the claim of Proposition 8,

$$E_{y''|y'}[W((y', y''), \emptyset)] \leq W(y', \emptyset), \quad (\text{A.3})$$

note that convexity of relative entropy (Cover and Thomas, Theorem 2.7.2) implies that for any  $y'$

$$\begin{aligned}
E_{y''|y'} [D(f(s_n|y', y'')||f(s_n))] &= \sum_{y''} f(y''|y') D(f(s_n|y', y'')||f(s_n)) \\
&\geq D \left( \sum_{y''} f(y''|y') f(s_n|y', y'') || f(s_n) \right) = D(f(s_n|y')||f(s_n)),
\end{aligned}$$

where we used that  $f(s_n|y', y'')$  is a mean-preserving spread of  $f(s_n|y')$ . This inequality is equivalent to (A.3).

Finally, combining (A.3) and (A.2) directly gives the second claim of Proposition 7.  $\square$

**Proof of Proposition 9 .** In text.  $\square$

**Proof of Proposition 10.** First, we argue that it is optimal for the issuer to induce some investors to acquire information. Suppose, toward a contradiction, that with the issuer's optimal set of securities no investor acquires information. Then, the optimal security is  $c_n^i(y_1, \emptyset)$  for some  $i$  for which  $y^i = y_1$ , and priced to make the investor indifferent between taking the security and an outside option. It is easy to construct a higher-profit menu. First, consider offering the above security for an  $i$  for which investors do not have information. Then, offer

the security  $c_n^i(y_1, z_{M'})$  for all  $i$  for which investors have information and  $y^i = y_1$ . As we have shown in Proposition 4, when priced to make an informed consumer with signal  $z_{M'}$  indifferent, this security is strictly more profitable than the one for uninformed consumers. Hence, offering these securities at a slightly lower price induces some consumers to acquire information and raises profits, a profitable deviation.

We proceed by ignoring investors' incentive-compatibility constraints (i.e., that informed and uninformed investors prefer the respective contracts intended for them), and show at the end that the profit-maximizing menu we identify satisfies them.

Suppose that with the issuer's optimal menu, the investor's perceived gain from acquiring information is  $x$ . We argue that a profit-maximizing way to create this perceived gain is exactly with the above menu. First, note that it is not optimal to leave the uninformed consumers with a surplus: if that was the case, the issuer could increase profits without changing the perceived gain from information by increasing all prices by the same amount so that uninformed consumers are indifferent. Second, Proposition 4 implies that the security that maximizes the issuer's profit given that an informed consumer gets a surplus of  $x$  is  $c_n^i(y_1, z_{M'})$  for an  $i$  for which investors have information and  $y^i = y_1$ ,  $z^i = z_{M'}$ . Since with the above menu the issuer sells such a security with probability 1, and the investor also perceives that it will get a surplus of  $x$  with probability 1, the issuer cannot do any better.

Given the above considerations, the issuer's problem is to choose  $x$  to maximize the resulting expected profit

$$\begin{aligned} \max_x G(x) & \left( \underbrace{\sum_n f(s_n^i | z_{M'}) \ln (c_n^i(y_1, z_{M'}) + \underline{c}) - \ln \underline{c} - \sum_n f(s_n^i | y_1) c_n^i(y_1, z_{M'})}_{\equiv p^{acq}} \right) + \\ & (1 - G(x)) \left( \underbrace{\sum_n f(s_n^i) \ln (c_n^i(y_1, \emptyset) + \underline{c}) - \ln \underline{c} - \sum_n f(s_n^i | y_1) c_n^i(y_1, \emptyset)}_{\equiv p^{n.acq}} \right), \end{aligned}$$

where the first term is the expected profit from informed consumers, the second term is the expected profit from uninformed consumers, and  $p^{acq}$  and  $p^{n.acq}$  are the prices of the two

securities. The first-order condition is

$$g(x) \left( \sum_n f(s_n^i | z_{M'}) \ln (c_n^i(y_1, z_{M'}) + \underline{c}) - \ln \underline{c} - x - \sum_n f(s_n^i | y_1) c_n^i(y_1, z_{M'}) \right) - G(x) - g(x) \left( \sum_n f(s_n^i) \ln (c_n^i(y_1, \emptyset) + \underline{c}) - \ln \underline{c} - \sum_n f(s_n^i | y_1) c_n^i(y_1, \emptyset) \right) = 0,$$

which we can rewrite as

$$D(f(s_n^i | z_{M'}) || f(s_n^i | y_1)) - D(f(s_n^i) || f(s_n^i | y_1)) = x + \frac{G(x)}{g(x)}. \quad (\text{A.4})$$

Finally, we have to check that the investors' incentive-compatibility conditions hold at this solution. This is obvious for informed investors: their perceived expected utility from choosing a security intended for them is  $x > 0$ , and their perceived expected utility from choosing a security intended for uninformed investors is 0. For uninformed investors, we want to show

$$\sum_n f(s_n^i) \ln \frac{f(s_n^i | z_{M'})}{f(s_n^i | y_1)} - \sum_n f(s_n^i) \ln \frac{f(s_n^i)}{f(s_n^i | y_1)} = \sum_n f(s_n^i) \ln \frac{f(s_n^i | z_{M'})}{f(s_n^i)} \leq p^{acq} - p^{n.acq}.$$

Note that the left hand side is  $-D(f(s_n^i) || f(s_n^i | z_{M'})) < 0$ . In contrast, (A.4) and that uninformed investors get zero surplus,  $p^{acq} - p^{n.acq} = \frac{G(x)}{g(x)} > 0$ , so that the above inequality holds. □

**Proof of Proposition 11.** In text. □

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