

Financial Innovation and Portfolio Risks

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Financial markets have recently experienced innovations that vastly increased trading opportunities. Since 1960s, there has been a rapid expansion of new financial products such as various types of futures, options, and more exotic derivatives (see Miller (1986)). There has also been improvements in information technology that have dramatically reduced trading costs (see Turley (2012)). The traditional view in finance suggests that these innovations should facilitate *risk sharing* (see, for instance, Allen and Gale (1994)). However, this view does not take into account that traders might naturally disagree about how to value assets. In fact, a separate strand of the finance literature has emphasized the importance of belief disagreements to explain various features of financial markets (see Hong and Stein (2007)). Belief disagreements naturally lead to *speculation*, which tends to *increase* risks in direct contrast with the traditional risk sharing view.

In recent research (Simsek (2012)), I systematically analyze the channels by which financial innovation affects portfolio risks in an environment with both risk sharing needs and belief disagreements. In this paper, I illustrate these channels using a simplified example. In addition to the creation of new assets, which I refer to as *product innovation* and which is the focus of Simsek (2012), I also consider reductions in transaction costs, which I loosely refer to as *process innovation*. When belief disagreements are sufficiently large, both types of innovation *increase* traders' portfolio risks. Perhaps surprisingly, product innovation increases risks even if traders do not disagree about how to value new assets. This is because of a subtle economic force, the *hedge-more/bet-more* effect, by which new assets amplify traders' speculation on existing disagreements.

I also analyze *endogenous financial innovation* by considering the assets that would be introduced by a profit seeking market maker. The market maker's incentives are driven not only

by the risk sharing motive for trade as emphasized in the previous literature (see the survey in Duffie and Rahi (1995)), but also by the speculation motive. When disagreements are large, speculation is the dominant force and the optimal asset design *increases* portfolio risks.

Taken together, these results suggest that belief disagreements can substantially change the effect of recent financial innovations on portfolio risks, as well as the driving force behind some of those innovations.

I. Basic Environment

Consider an economy with two dates, $\{0, 1\}$, and a single consumption good, which will be referred to as a dollar. There are a finite number of traders denoted by $i \in I$. Each trader's endowment at date 0 is normalized to 0 (for simplicity). Trader i is also endowed with w_i dollars at date 1, which is a random variable that captures the trader's background risks. At date 1 (and only then), traders consume. At date 0, traders can save or borrow at a riskless rate normalized to 0. In addition, they can also take positive or negative positions in risky assets denoted by $j \in J$. Asset j is in fixed supply, normalized to zero, and it pays a^j dollars at date 1, which is a random variable.

Let p^j denote the price of asset j and x_i^j denote the trader's position. Suppose the trader that takes this position also pays a quadratic transaction cost given by $\frac{c^j}{2} (x_i^j)^2$, where $c^j \geq 0$. This cost can be viewed as part of the commissions or the bid-ask spreads that compensate the middlemen (e.g., dealers, exchange specialists) for their time and effort in making a market.¹ The trader's net worth at date 1 can then be written as:

$$(1) \quad n_i = \sum_{j=1}^J \left(x_i^j (a^j - p^j) - \frac{1}{2} c^j (x_i^j)^2 \right) + w_i.$$

¹In particular, I abstract away from transaction costs that stem from information asymmetries (e.g., adverse selection).

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Trader i maximizes subjective expected utility over net worth at date 1. Her utility function takes the CARA form. I assume that asset payoffs and background risks are jointly Normally distributed, so that the trader's optimization reduces to the usual mean-variance problem:

$$(2) \quad \max_{\{x_i^j\}_j} E_i [n_i] - \frac{\theta_i}{2} \text{var}_i [n_i].$$

Here, $E_i [\cdot]$ and $\text{var}_i [\cdot]$ denote the mean and the variance of the trader's portfolio according to her belief, and θ_i denotes her absolute risk aversion coefficient. The equilibrium is a collection of asset prices and portfolios such that each trader i chooses her portfolio optimally and markets clear, i.e., $\sum_i x_i^j = 0$ for each $j \in J$.

This model can be used to analyze the effect of financial innovation on portfolio risks. Recent years have seen at least two distinct types of financial innovation. First, a large number of new financial assets have been introduced to trade since 1960s. Duffie and Rahi (1995) mention that there were roughly 1200 different types of derivative securities being used as of 1994 (either in exchanges or over-the-counter markets). I refer to these developments as *product innovation* and capture them as an expansion of the set, J , of traded assets. Second, there has also been dramatic reductions in trading costs. Turley (2012) documents that the total cost of round trip trading (buying and selling) a typical stock has declined from about 5% of the stock price in 1975 to less than 0.1% in recent years. This decline is partly due to deregulation but to a greater extent due to improvements in information technology. I refer to these developments loosely as *process innovation* (following the taxonomy in Tufano, 2004) and capture them as a reduction of transaction costs, $\{c^j\}_j$.

In Simsek (2012), I analyze product innovation for a general specification of background risks and assets. In this paper, I consider both product and process innovation, but I restrict attention to a simple example. Suppose there are two traders, i.e., $I = \{1, 2\}$, with the same risk aversion coefficients, i.e., $\theta_1 = \theta_2 \equiv \theta$. The underlying uncertainty is captured by two uncorrelated random variables, v_1, v_2 . Traders' background risks are perfectly correlated with one another, and they depend on a combination of

the underlying random variables, that is:

$$(3) \quad w_1 = v \text{ and } w_2 = -v, \text{ where } v = v_1 + \alpha v_2.$$

To keep the expressions simple, suppose also that $c^j \equiv c$ for each asset $j \in J$.

As a benchmark, suppose there are no financial assets. In this case, there is no trade and traders' net worths are the same as their background risks. In particular, traders are unable to hedge their endowment risks, which leads to portfolio risks in equilibrium.

II. Financial innovation with pure risk sharing

I first use this example to illustrate the traditional risk sharing view of financial innovation. To this end, suppose traders have common beliefs about v_1 and v_2 given by $N(0, 1)$. First consider product innovation. Suppose a new asset, $j = 1$, is introduced to trade whose payoff is perfectly correlated with traders' endowments, $a^1 = v$. In equilibrium, trader 1's portfolio and net worth are given by:

$$(4) \quad x_1^1 = \frac{-\theta(1 + \alpha^2)}{\theta(1 + \alpha^2) + c}, \quad n_1 = \frac{c}{\theta(1 + \alpha^2) + c}v,$$

trader 2's portfolio and net worth are given by mirror-image expressions, and $p^1 = 0$. With common beliefs, the introduction of asset 1 enables traders to diversify their idiosyncratic risks. This leads to a reduction in portfolio risks as illustrated by the fact that $\frac{c}{\theta(1 + \alpha^2) + c} < 1$.

Next consider process innovation, that is, a reduction in transaction costs, c . With lower costs, traders naturally take greater risk sharing positions. This leads to a further reduction in their portfolio risks as illustrated by the fact that the term, $\frac{c}{\theta(1 + \alpha^2) + c}$, is increasing in c . It follows that, when traders have common beliefs, both product and process innovation facilitates risk sharing and reduces portfolio risks.

III. Financial innovation with speculation and risk sharing

I next consider the effect of financial innovation when traders might also have a speculative motive for trade. The key assumption is that traders have belief disagreements about some of the uncertainty in this economy [cf. Eq. (3)]. In

particular, suppose traders have common beliefs for v_2 given by the distribution, $N(0, 1)$. They also know that v_1 and v_2 are uncorrelated. However, they disagree about the distribution of v_1 . Trader 1's prior belief for v_1 is given by $N(\varepsilon, 1)$ while trader 2's belief is given by $N(-\varepsilon, 1)$. Importantly, traders also know each other's belief, that is, they agree to disagree. The parameter, ε , captures the level of the disagreement.

In Simsek (2012), I analyze the effect of belief disagreements generally and show that product innovation increases portfolio risks through two distinct channels. In this paper, I also consider process innovation and show that it makes the second channel in Simsek (2012) even stronger. I next illustrate these two channels.

Channel 1: Product innovation generates new disagreements.

With belief disagreements, the equilibrium after the introduction of asset 1 is different than in Eq. (4) and is given by:

$$(5) \quad x_1^1 = \frac{-\theta(1 + \alpha^2) + \varepsilon}{\theta(1 + \alpha^2) + c}, \quad n_1 = \frac{\varepsilon + c}{\theta(1 + \alpha^2) + c} v.$$

Note that traders' positions deviate from the optimal risk sharing benchmark in Eq. (4) in view of their disagreement, ε . If the disagreement is sufficiently strong, i.e., $\varepsilon > \theta(1 + \alpha^2)$, then trader 1 is so optimistic about the payoff of the new asset that she takes a positive position, $x_1^1 > 0$, even though risk sharing would require her to take a negative position. As this happens, product innovation *increases* portfolio risks (since $\frac{\varepsilon + c}{\theta(1 + \alpha^2) + c} > 1$). Intuitively, the new asset generates a new disagreement and a new source of speculation.

Channel 2: Process and product innovation amplify speculation on existing disagreements.

Eq. (5) also illustrates the effect of process innovation on portfolio risks. Under the same assumption, $\varepsilon > \theta(1 + \alpha^2)$, a reduction in transaction costs, c , further *increases* portfolio risks (since $\frac{\varepsilon + c}{\theta(1 + \alpha^2) + c}$ is decreasing in c). When trader 1 is sufficiently optimistic, she is taking a net speculative position on the new asset. As trading costs decline, she takes a greater speculative position. Consequently, process inno-

vation increases portfolio risks by amplifying speculation on existing disagreements.

In Simsek (2012), I show that product innovation increases portfolio risks also through the same channel as process innovation. To see this, suppose $c = 0$ so there is no scope for process innovation. Consider the introduction of a second asset with payoff, $a^2 = v_2$. This asset does not generate a new disagreement because traders agree on its payoff. Nonetheless, this asset also increases portfolio risks. To see this, consider trader 1's positions and net worth given by:

$$(6) \quad x_1^1 = -1 + \frac{\varepsilon}{\theta}, \quad x_1^2 = -\alpha \frac{\varepsilon}{\theta}, \quad \text{and} \quad n_1 = \frac{\varepsilon}{\theta} v_1.$$

The trader's portfolio risks are greater than the case with a single asset, as can be seen by comparing the variance of n_1 in Eqs. (6) and (5).

The intuition for this result is related to an important economic force: the *hedge-more/bet-more* effect. When only asset 1 is available, traders' portfolio risks are decreasing in α , the share of v_2 in asset 1's payoff [cf. Eq. (5)]. Intuitively, asset 1 provides traders with only *impure bets* because its payoff also depends on the risk, v_2 , on which traders do not disagree. To take speculative positions, traders must also hold these additional risks, which makes betting effectively costly. When asset 2 is also available, traders complement their speculative positions in asset 1 by taking the opposite positions in asset 2, as illustrated by x_1^2 in Eq. (6). This enables them to take purer bets on the risk, v_1 . When traders are able to take purer (and effectively cheaper) bets, they also take larger bets and hold riskier portfolios.

IV. Endogenous financial innovation

The analysis so far took the set of assets as exogenous. In practice, financial products are often introduced by economic agents with profit incentives. The previous literature has emphasized risk sharing as a major driving force for endogenous financial innovation [e.g., Allen and Gale (1994), Duffie and Rahi (1995), Athanassoulis and Shiller (2001)]. A natural question, in view of the earlier results, is whether the risk sharing motive for innovation is robust to the presence of belief disagreements.

I next address this question by endogenizing the introduction of assets in the example. Sup-

pose the assets are designed by a profit seeking market maker who is constrained to introduce a single asset. Without loss of generality, suppose the asset has payoff:

$$a^1 = v_1 + \gamma v_2,$$

and that the market maker chooses the relative weight, γ . For simplicity, suppose there are no transaction costs, i.e., $c = 0$. The market maker intermediates trade in this asset which enables it to extract some of the surplus from traders. Suppose the market maker extracts a constant fraction of the full surplus. Then, she chooses an asset design, γ , that maximizes the full surplus, $\sum_{i \in I} \pi_i(\gamma)$, where $\pi_i(\gamma)$ is the trader's willingness to pay to trade the asset. In view of the mean-variance framework, $\pi_i(\gamma)$ is also equal to traders' certainty equivalent wealth in equilibrium with the new asset (according to her own belief) relative to her certainty equivalent wealth without the asset.

In Simsek (2012), I characterize the optimal unconstrained asset design for a general setting that embeds this example. Here, I simplify the analysis further by assuming that the market maker is also constrained to choose one of two designs, $\gamma \in \{0, \alpha\}$. Note that $\gamma = \alpha$ results in an asset that is perfectly correlated with agents' portfolio risks. Hence, the design, $\gamma = \alpha$, can be viewed as financial innovation directed towards risk sharing. In contrast, $\gamma = 0$ results in an asset whose payoff is perfectly correlated with the uncertainty on which traders disagree, v_1 . Hence, the design, $\gamma = 0$, can be viewed as financial innovation directed towards speculation. I next characterize the type of financial innovation prevails in this market.

The design $\gamma = \alpha$ results in the allocations in characterized in Eq. (5) with $c = 0$. The willingness to pay for each trader $i \in \{1, 2\}$ can be calculated as:

$$(7) \quad \pi_i(\gamma = \alpha) = \left[\frac{1}{2\theta} \frac{\varepsilon^2}{(1 + \alpha^2)} - \varepsilon \right] + \frac{1}{2}\theta (1 + \alpha^2).$$

Here, the second term can be viewed as the trader's gain from reduced portfolio risks, whereas the first term (in brackets) can be viewed as her perceived gain from speculation. Similarly, the trader's willingness to pay for de-

sign $\gamma = 0$ can be calculated as:

$$(8) \quad \pi_i(\gamma = 0) = \left[\frac{1}{2} \frac{\varepsilon^2}{\theta} - \varepsilon \right] + \frac{1}{2}\theta.$$

In this case, the gain from risk reduction is smaller since the asset is imperfectly correlated with the trader's background risk. However, the gain from speculation is greater because the asset enables the trader to take a purer bet.

Comparing Eqs. (7) – (8) illustrates the nature of financial innovation in this example. If the disagreement, ε , is sufficiently small (relative to θ), then the market maker introduces the risk sharing design, $\gamma = \alpha$. In contrast, if ε is sufficiently large, then the market maker introduces the speculative design, $\gamma = 0$. In Simsek (2012), I show that this result holds more generally: When disagreements are sufficiently large, e.g., as $\varepsilon \rightarrow \infty$ in the example, the market maker introduces assets that *maximize* portfolio risks among all possible choices, completely disregarding the risk sharing motive in innovation. Intuitively, with large disagreements, speculation becomes the main motive for trade. Consequently, a profit seeking market maker introduces assets that enable the traders to speculate most precisely on their different views (which corresponds to the design, $\gamma = 0$, in the example). As a by-product, the speculative design also maximizes traders' portfolio risks.

V. Welfare implications

Although the results so far have established that financial innovation can increase portfolio risks, they have not reached any welfare conclusions. In fact, it can be seen that financial innovation in the above example leads to a Pareto improvement. This is because each trader perceives a large expected return from her speculative positions, which justifies the increase in her portfolio risks. In Simsek (2012), I show that this welfare conclusion can be overturned in two natural variants of the baseline environment.

The first setting concerns an interpretation of disagreements as *distortions* stemming from various psychological biases emphasized in behavioral finance (see Barberis and Thaler (2003) for a survey). In this case, the Pareto criterion is arguably not appropriate. Traders' welfare should ideally be evaluated according to the

objective (or non-distorted) belief.² However, there is a practical difficulty because the planner might not know the objective belief. In Brunnermeier, Simsek, and Xiong (2012), we propose a *belief-neutral welfare criterion* that circumvents this difficulty. Loosely speaking, this criterion identifies an outcome as inefficient only if it is inefficient according to *any belief* that lies in the convex combination of traders' beliefs. Applying this criterion in the example detects financial innovation as inefficient whenever it increases portfolio risks. The key insight is that trading in this economy does not generate expected net worth in the aggregate since it simply redistributes wealth. When portfolio risks increase, each trader recognizes that financial innovation leads to a socially inefficient outcome. Put differently, each trader believes her welfare is increasing at the expense of other traders. Consequently, a planner can conclude that financial innovation is inefficient *without taking a stand on whose belief is correct*.

The second setting analyzed in Simsek (2012) concerns situations in which traders' decisions are associated with externalities. Such externalities naturally emerge when traders are viewed as financial intermediaries. Among other things, financial intermediaries are generally viewed as enjoying explicit or implicit government protection. When this is the case, intermediaries' portfolio choices represent externalities on the government. Moreover, the government's expected losses depend on a measure of portfolio risks, because these risks determine the extent to which the intermediaries will need government protection. Consequently, financial innovation that increases portfolio risks also exacerbates the negative externalities, and might lead to an inefficiency even according to the Pareto criterion.

Importantly, in both settings traders' portfolio risks emerge as a central object of welfare analysis, providing some normative content to the earlier results. However, these results should be viewed as partial exercises, characterizing the welfare effects of financial innovation that operate through portfolio risks. In particular, I do not make any policy recommendations regarding financial innovation. This is because my

analysis is missing some important ingredients that could change the welfare arithmetic. Most notably, speculation driven by financial innovation could provide additional social benefits by making asset prices more informative. Assessing the net welfare effect of financial innovation is a fascinating question which I leave for future research.

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²In a related model, Weyl (2007) shows that cross-market arbitrage can reduce social welfare according to the objective belief.