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RESEARCH ARTICLE

Strict certainty preference in the predictive brain: a new perspective on financial innovations and their role in the real economy

Hammad Siddiqi[1]

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Abstract
The dominant paradigm in neuroscience considers the brain to be a prediction engine. The brain generates predictions first, which are then contrasted with information to generate error signals. Finite brain resources are subsequently spent in selectively processing the error signals based on their relative value with higher value signals getting a priority. In this way, the brain can be thought of as optimizing on its own internal resources before seeking to optimize on the resources available in the external world. We show that such considerations change the cost–benefit calculations of certain vs uncertain outcomes in the brain, giving rise to, what can be termed as, a strict certainty preference. A new perspective on prominent financial innovations (such as securitization, interest rate swaps, and credit default swaps) emerges, with a dark side that potentially leads to a misallocation of resources towards low NPV projects.

Keywords Financial innovation · Interest rate swaps · Securitization · Credit default swaps

JEL Classification G00 · G30 · G10

1 Introduction

Many financial innovations in the last few decades are aimed at capturing the benefits from safe cash flows with such innovations also sharing the blame for creating new systemic risks that led to the 2008 global financial meltdown (Gennaioli and Vishny 2012, Caballero 2010). An intriguing question is: Why does explicitly spitting a payoff pool into risky and safe financial assets (as in 'securitization') or implicitly considering the risky and safe payoffs separately (as in 'credit default swaps' or 'interest

✉ Hammad Siddiqi
hsiddiqu@usc.edu.au

1 University of the Sunshine Coast, Sippy Downs, Australia

rate swaps') adds value? In this article, we argue that modern neuroscience research about information processing in the brain provides an answer. We show that this neuroscience-based perspective on recent financial innovations highlights a dark side of financial innovations that potentially leads to a misallocation of resources towards low NPV projects.

The now dominant paradigm in neuroscience research is that the brain is a prediction engine. The brain generates predictions first, which are then contrasted with information to generate error signals. As spending the brain resources on processing of error signals incurs a cost, the brain efficiently processes error signals based on their relative value with higher value signals getting a priority.[1]

What are the direct implications of the above-mentioned neuroscience perspective on investor decisions? To fix ideas, consider an investor choosing between a safe bank account and the stock market to invest \$100. If she chooses the safe bank account, she is certain that her investment will grow to \$105 in one year's time. So, there won't be any error signals in the predictive brain that need to be processed. However, if she invests in the stock market, she predicts that she is likely to get \$110 back in a year. However, she knows that her investment will be subject to the ups and downs in the market with new information potentially generating 'error signals' in her brain several times that need to be processed. Furthermore, adverse 'error signals' such as associated with a loss, may trigger a further costly stress response in her brain and body. How does she decide which option to choose? Her decision is based on the comparison of the utility benefit from the safe \$105 with the utility benefit from the risky \$110 plus the anticipated costs associated with processing of the error signals (including any stress response) which are inevitable in the risky scenario.

Such additional costs are consistent with strict safety preference (also known as disproportionate safety preference) found in the economics and finance literature. There is a growing body of evidence consistent with decision-makers displaying a strict safety preference or disproportionate preference for safety (see Serfilippi et al (2019)). Andreoni and Sprenger (2010) show that Allais paradoxes (common consequence, and common ratio), as well as other prominent decision-making anomalies, can be understood by incorporating a disproportionate preference for safety in the expected utility framework. In general, violations of standard expected utility maximization are substantially less prevalent when only uncertain payoffs are involved (Camerer 1992; Harless and Camerer 1994; Starmer 2000), indicating that behavior at or close to certainty is fundamentally different from behavior away from certainty. Andreoni and Sprenger (2012) present a discounted expected utility violation which is consistent with a disproportionate preference for safety with certain outcomes being assessed with a different utility function than uncertain outcomes. The results in Gneezy et al. (2006) are also indicative of certain outcomes being assessed differently than uncertain outcomes. Simonsohn (2009) reports similar results showing that risky prospects are evaluated below their worst outcomes consistent with a disproportionate preference

[1] There is a large body of literature in neuroscience that considers the brain to be a prediction machine. A sample based on writings of leading neuroscientists, which is suitable for a non-specialist audience includes chapter 3 in Hawkins (2021), chapter 4 in Feldman (2021a), chapter 4 in Seth (2021), chapters 4 and 5 in Goldstein (2020), Hohwy (2013), and Clark (2013, 2015) among others. Feldman (2021b) also provides a discussion of key ideas. For an application of predictive processing in economics, see Siddiqi (2024).

for safety.[2] Siddiqi (2017) considers its importance for financial innovations. However, the literature is largely silent on the reasons for such strict safety preference.

In this article, we argue that the modern neuroscience research brings to light a strong reason for such a strict safety preference, which arises due to the scarce brain resources being saved from error signal processing. We apply this view to recent financial innovations such as securitization, credit default swaps, and interest rate swaps that add value by either explicitly or implicitly separating risky and safe cash flows, and allowing firms to benefit from such separation. We show that a dark side to such financial innovations emerges which potentially causes a misallocation of resources at the firm level with low net present value (NPV) projects (with larger amounts of safe cash flows) getting preference over high NPV projects. Even negative NPV projects may be accepted. By encouraging such misallocation towards low or even negative NPV projects, recent financial innovations might have contributed to the productivity slowdown at the firm level. The current productivity slowdown afflicting core advanced economies predates the GFC-2008 and continues unabated even after the effects of the crisis have largely dissipated (Fernald 2014, Cete et al. 2016, Syverson 2017). This suggests that structural rather than cyclical factors are behind the slowdown consistent with the approach here. We further show that a low interest rate environment makes such misallocation towards low NPV projects worse, which makes a sustained period of loose monetary policy structural damaging to the economy.

The rest of the article is organized as follows. Section 2 presents the main results, and Sect. 3 concludes with a discussion on the effectiveness of monetary policy in a low interest rate environment given our results.

2 Recent financial innovations and benefits from safe cash flows

The clearest example of a financial innovation in which safe cash flows are explicitly carved-out from uncertain payoffs via a seniority structure is securitization. The primary motive of this type of financial innovation is the creation of AAA-rated securities (Gennaioli et al. 2012, Caballero 2010), which are in high demand from investors and pension funds. Securitization accomplishes this by pooling cash flows and creating a seniority structure that effectively carves-out the safest bits, which are then re-packaged and sold separately as AAA securities. However, a financial innovation does not have to explicitly carve-out safe cash flows to capture their benefits as there are many indirect ways of doing so. Consider a plain vanilla interest rate swap (IRS). IRS contracts constitute about 60% of the global OTC derivatives trade, which, at 10 times the world GDP, is arguably the most significant market for any financial instrument in the world (Bank for International Settlement 2017). A typical IRS contract is between a firm and a bank in which the firm pays a fixed-rate to the bank in exchange for the bank paying a variable-rate (Fontana et al. 2019). This arrangement effectively transforms a short-term variable-rate loan that the firm owes the bank to a long-term fixed-rate loan. To fix ideas, suppose a firm already has a short-term loan at *LIBOR*

[2] Such a preference for safety may arise in a resource-constrained rational brain that first optimizes on its own internal resources before optimizing on the resources available in the external world (Siddiqi and Murphy 2023, Siddiqi 2023)).

+ *Spread*. It then enters into a long-term IRS contract with the bank in which it pays *FIXED* and receives *LIBOR* on a notional amount equal to the size of the loan. Effectively, the loan now costs a fixed rate, which is, *FIXED* + *LIBOR* + *Spread* − *LIBOR* = *FIXED* + *Spread*. If the firm has plenty of safe cash flows and continues to generate them then it would have lower counterparty risk, with the bank not only charging a lower *FIXED* now but also lower *Spread* in the future when the short-term variable rate loan is rolled over. In this manner, conservatism is dynamically rewarded in the investment choices of the firm, with safe cash flows benefiting the firm without any explicit carving-out (Kupriyanov 1994; Wall and Pringle 1989).

Another example of a financial innovation that lets firms capture the benefits from safe cash flows without any explicit carving-out is a credit default swap (CDS). A CDS seller insures the CDS buyer against default by a firm on its corporate bonds. A spread, known as CDS spread, is charged for providing this protection. One can see the same trend towards dynamically rewarding conservatism as introduction of the CDS market has been shown to make firms more liquidity conscious (Subrahmanyam et al. 2017) as firms desire to keep the CDS spreads on their corporate bonds low.

In what follows, it does not matter whether the safe cash flows are explicitly carved-out and sold separately as AAA bonds, or the benefits are implicitly captured as in the case of IRS and CDS contracts. The only requirement is that safe cash flows are considered separately from risky ones.

There are a number of essentially equivalent ways of distinguishing between the utility from certain and uncertain outcomes. One can explicitly add the anticipated error signal processing costs to the uncertain outcomes, which amounts to lowering the overall utility from the uncertain outcomes by some factor. Equivalently, one can increase the certain utility by a corresponding factor, which is the approach adopted in the literature on certain and uncertain utility (Andreoni and Sprenger 2010, Siddiqi 2017, Serflippi et al. 2019, Siddiqi 2023). In conformity with the literature, we take the same approach here. That is, the setting of the optimization problem is standard and is the same as the literature on certain and uncertain utility.[3]

Suppose there is a firm considering two mutually exclusive projects: A and B. For simplicity and without any loss of generality, assume that they both require the same initial investment of C, and have a life of one period at the end of which, they generate uncertain payoffs of $\widetilde{X}_A$ and $\widetilde{X}_B$ respectively. There are no other expenses or inflows. The decision to choose between the projects depends on their NPVs:

$$NPV_A = PV\left(\widetilde{X}_A\right) - C \tag{2.1}$$

$$NPV_B = PV\left(\widetilde{X}_B\right) - C \tag{2.2}$$

It is important to note that in (2.1) and (2.3), the present value, denoted by PV(.) is not based on discounting by the risk-free rate. Rather, it is based on discounting at the appropriate risk-adjusted discount rate. There is a representative agent whose

[3] As pointed out in the earlier literature on certain and uncertain utility, Modigliani and Miller propositions require that certain and uncertain outcomes are evaluated with the same utility function; hence, their results do not apply here.

behavior determines discount rates. The agent is assumed to have a disproportionate preference for safety as in Andreoni and Sprenger (2010) and Siddiqi (2017). That is, certain and uncertain utility functions are related as follows:

$$u^s(c_t) = (1+\alpha)u^R(c_t) \tag{2.3}$$

where $\alpha \geq 0$

Risky or uncertain outcomes are evaluated with the utility function, $u^R(c_t)$, and certain outcomes are evaluated with the utility function, $u^s(c_t)$. Otherwise, these utility functions obey the standard properties (see Andreoni and Sprenger (2010)). The parameter, α, captures the strength of disproportionate preference for safety when its value is larger than 0. We revert to the classical case without a disproportionate preference for safety when $\alpha = 0$. Proposition 1 shows the relationship between discount rates with and without a disproportionate preference for safety.

Proposition 1 Risky cash flows are discounted at a higher rate, $\mathrm{R_U^D}$, when there is a disproportionate preference for safety when compared with the discount rate, $\mathrm{R_U}$, without such preference. The discount rates are related as: $\mathrm{R_U^D} = \mathrm{R_U}(1+\alpha)$. The risk-free discount rate, $\mathrm{R_F}$ remains the same regardless of the safety preference.

Proof The discount rate for risky cash flows without a disproportionate safety preference, R_U, can be inferred from the following:

$$\frac{E\left[\widetilde{X}\right]}{R_U} = \beta E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)} \cdot \widetilde{X}\right] = \beta\left\{E\left[\widetilde{X}\right]E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right] + cov\left(\widetilde{X}, \frac{u'^R(c_{t+1})}{u'^R(c_t)}\right)\right\} \tag{2.4}$$

where $B < 1$ is time-discount.

Also,

$$\beta E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right] = \frac{1}{R_F}$$

where R_F is the risk-free discount rate.

It follows that:

$$R_U = \frac{R_F \cdot E\left[\widetilde{X}\right]}{E\left[\widetilde{X}\right] + cov\left(\widetilde{X}, \frac{\frac{u'^R(c_{t+1})}{u'^R(c_t)}}{E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right]}\right)} \tag{2.5}$$

The market value of risky cash flows with a disproportionate preference for safety can be inferred from:

$$P_t \cdot u'^s(c_t) = \beta E\left[u'^R(c_{t+1}) \cdot \widetilde{X}_{t+1}\right] \tag{2.6}$$

Note, that paying the price for an asset is a certain expense, hence, evaluated with the utility function, $u^s(c_t)$, whereas receiving payoffs from the asset is an uncertain or risky gain, hence, evaluated with the utility function, $u^R(c_t)$. Hence, the discount rate for risky cash flows with a disproportionate safety preference, R_U^D, can be inferred from:

$$\begin{aligned} P_t &= \frac{E\left[\tilde{X}\right]}{R_U^D} \\ &= \frac{\beta}{(1+\alpha)} E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)} \cdot \tilde{X}\right] \\ &= \frac{\beta}{(1+\alpha)} \left\{ E\left[\tilde{X}\right] E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right] + cov\left(\tilde{X}, \frac{u'^R(c_{t+1})}{u'^R(c_t)}\right) \right\} \end{aligned} \tag{2.7}$$

which simplifies to:

$$R_U^D = \frac{(1+\alpha)\cdot R_F \cdot E\left[\widetilde{X}\right]}{E\left[\widetilde{X}\right] + cov\left(\widetilde{X}, \frac{\frac{u'^R(c_{t+1})}{u'^R(c_t)}}{E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right]}\right)} = (1+\alpha)R_U \tag{2.8}$$

The risk-free rate with disproportionate preference for safety is the same as the risk-free rate without such preference as:

$$\beta E\left[\frac{u'^s(c_{t+1})}{u'^s(c_t)}\right] = \beta E\left[\frac{(1+\alpha)u'^R(c_{t+1})}{(1+\alpha)u'^R(c_t)}\right] = \beta E\left[\frac{u'^R(c_{t+1})}{u'^R(c_t)}\right] = \frac{1}{R_F}$$

□

It makes intuitive sense that risky cash flows are more heavily discounted when there is a disproportionate preference for safety. As safe cash flows are discounted at the same rate, with and without safety preference, splitting payoffs into risky and safe components adds value. Without the safety preference, that is, when $\alpha = 0$, it does not really matter how a given cash flow is split between risky and safe components. However, with safety preference, that is, when $\alpha > 0$, risky cash flows are more heavily discounted, so considering safe and risky cash flows separately adds value.

Financial innovations that aim to capture the benefits from safe cash flows induce a separate consideration of safe cash flows in project evaluation. So, cash flows from project A are viewed as $\widetilde{X}_A = \left(\widetilde{X}_A - K_A\right) + K_A$ and cash flows from project B are viewed as $\widetilde{X}_B = \left(\widetilde{X}_B - K_B\right) + K_B$ where K_A and K_B are safe cash flows generated by project A and project B respectively.

Without a disproportionate preference for safety, that is, when $\alpha = 0$, the present value remains unchanged regardless of how the cash flows are split:

$$PV\left(\widetilde{X}\right) = PV\left(\widetilde{X} - K\right) + PV(K)$$

$$\Rightarrow \frac{E\left[\widetilde{X}\right]}{R_U} = \frac{E\left[\widetilde{X} - K\right]}{R_{U'}} + \frac{K}{R_F} \tag{2.9}$$

where $R_U' > R_U$. When K is split-off, it gets discounted at a lower rate, however, the remaining risky cash flow component is then discounted at a higher rate, which keeps the total value the same.

With a disproportionate preference for safety, that is, when $\alpha > 0$, the present value of unsplit cash flows is calculated as:

$$PV\left(\widetilde{X}\right) = \frac{E\left[\widetilde{X}\right]}{R_U^D} = \frac{E\left[\widetilde{X}\right]}{(1+\alpha)R_U} = \frac{1}{(1+\alpha)}\left\{\frac{E\left[\widetilde{X} - K\right]}{R_U'} + \frac{K}{R_F}\right\} \tag{2.10}$$

where $R_U^D = (1+\alpha)R_U$ (proposition 1) is used above with a further substitution for $\frac{E\left[\widetilde{X}\right]}{R_U}$ made from (2.9).

When safe and risky cash flows are considered separately, the present value is:

$$PV\left(\widetilde{X} - K\right) + PV(K) = \frac{E\left[\widetilde{X} - K\right]}{R_U^D} + \frac{K}{R_F} = \frac{E\left[\widetilde{X} - K\right]}{(1+\alpha)R_U'} + \frac{K}{R_F} \tag{2.11}$$

Subtracting (2.10) from (2.11) shows that considering safe and risky cash flows separately increases the overall present value by:

$$\Delta PV = PV\left(\widetilde{X} - K\right) + PV(K) - PV\left(\widetilde{X}\right) = \frac{\alpha K}{(1+\alpha)R_F} \tag{2.12}$$

The above analysis indicates that framing of a project evaluation problem is of critical importance. If risky cash flows are considered as a whole and not split into risk-free and residual risky components, then the present value is smaller. However, if, one splits cash flows into risky and risk-free components before discounting then the overall present value is larger. By making it possible to capture benefits from safe cash flows, recent financial innovations have re-framed project evaluation as a decision-problem involving a separate consideration of safe cash flows from the rest.

Proposition 2 follows.

Proposition 2 Separating cash flows into safe and risky components increases the overall present value. The amount by which the value increases is given by $\frac{\alpha \mathrm{K}}{(1+\alpha)\mathrm{R_F}}$ making projects with higher amounts of safe cash flows more attractive.

Empirically, one sees this re-framing in action when the introduction of CDS market on corporate bonds makes firms more liquidity conscious (Subrahmanyam et al.

2017) or when the introduction of IRS market makes firms more conservative in their investment choices (Kuprianov 1994, Wall and Pringle 1989). Arguably, we witnessed the devastating result of this re-framing when the securitization of subprime mortgages made offering such mortgages more attractive for banks than marginally prime mortgages (Mian and Sufi 2009).

Relevant comparative statistics show that:

1. A cut in interest rates increases the benefit from such re-framing as:

$$\frac{\partial \Delta PV}{\partial R_F} = -\frac{\alpha K}{(1+\alpha)R_F^2} < 0$$

2. Interest rate cuts have more bite in a low-rate environment as:

$$\frac{\partial^2 \Delta PV}{\partial {R_F}^2} = \frac{\alpha K}{(1+\alpha)R_F^3} > 0$$

3. Size of the safe cash flows increases the benefits from such re-framing as:

$$\frac{\partial \Delta PV}{\partial K} = \frac{\alpha}{(1+\alpha)R_F} > 0$$

4. Stronger preference for safety increases the benefits as well:

$$\frac{\partial \Delta PV}{\partial \alpha} = \frac{K}{(1+\alpha)^2 R_F} > 0$$

Such re-framing may alter the preference ranking of projects as well. Continuing with the case discussed in the beginning of this section, even when project A should be preferred over project B based on NPV analysis; if project B has larger amount of safe cash flows, then re-framing may cause project B to be accepted over project A. Proposition 3 follows.

Proposition 3 (Misallocation of resources) When cash flows are split into safe and risky components then a low NPV project may be preferred over a high NPV project provided it generates a larger amount of safe cash flows.

Proof Suppose NPV of project A is larger than NPV of project B:

$$NPV_A = PV\left(\widetilde{X}_A\right) - C > NPV_B = PV\left(\widetilde{X}_B\right) - C$$

$\Rightarrow PV\left(\widetilde{X}_A\right) > PV\left(\widetilde{X}_B\right)$

Re-framing cash flows as safe and residual risky, if $K_A < K_B$, then it is possible:

$$PV\left(\widetilde{X}_A\right) + \frac{\alpha K_A}{(1+\alpha)R_F} < PV\left(\widetilde{X}_B\right) + \frac{\alpha K_B}{(1+\alpha)R_F}$$

Hence, a low NPV project may be accepted at the expense of higher NPV project. □

Corollary 3.1 Even a negative NPV project may be selected.

Proof Suppose the initial cost is larger than the present value of inflows, that is: $C > PV\left(\widetilde{X}\right)$. As this project has negative NPV, it should be rejected. However, in the presence of financial innovations inducing re-framing of cash flows into safe and risky components, the following may hold: $PV\left(\widetilde{X}\right) + \frac{\alpha K}{(1+\alpha)R_F} > C$. Hence, a negative NPV project may be accepted. □

Before the financial innovations aimed at capturing the benefits from safe cash flows started gaining importance (interest rate swaps and securitization in the 80 s), there was no obvious reason for a firm to split cash flows into safe and risky components. For example, corporate bonds are never risk-free so funding a project through corporate bonds wouldn't lead to a separate consideration of risk-free and risky cash flows. However, with financial innovations aimed at capturing the benefits from safe cash flows, such as interest rate swaps, credit default swaps, and securitization, re-framing of cash flows into risk-free and residual risky components makes good sense. Projects with larger amounts of safe cash flows become more attractive, so project rankings without cash-flow splitting may differ from the ranking with such splitting. An otherwise low or even negative NPV project may be accepted due to such splitting.

Even though private sector debt is never risk-free, sectors that generate large amounts of safe cash flows s tend to rely more on debt, so one can use debt-reliance as a measure of safe cash flows in a sector. For example, housing and energy sectors carry more debt than the software sector as they have more safe cash flows. So, when the software sector is booming, one expects the misallocation of resources to be less severe as there aren't large safe cash flows in the sector. This is consistent with the empirical findings that from the mid 90's to early twenty-first century (booming software sector), productivity growth in the US was a decent 3% before collapsing to 1.2% after 2003 (booming housing sector) (Syverson 2017).

Proposition 4 The adverse impacts of financial innovations aimed at slitting cash flows into safe and risky components are larger when interest rates are low.

Proof Follows from realizing that as interest rates fall $\frac{\alpha K}{(1+\alpha)R_F}$ gets larger, which makes the misallocation noted in proposition 3 and corollary 3.1 worse.

The results here indicate that the traditional channel of expansionary monetary policy that operates by increasing the NPV as the discount rate falls is not the only channel. There are detrimental impacts that operate by causing a misallocation of resources towards low NPV projects as well as by widening the value-gap between large and small firms.

3 Discussion and conclusions

The traditional channel through which expansionary monetary policy affects the production side of the economy is as follows: An interest rate cut lowers the discount rates on projects; hence, pushing-up their NPVs. This leads to more projects being accepted; hence, more investments. In this manner, the production side of the economy is positively affected. This article argues that there is an additional channel on the production side, which affects the production side of the economy negatively. This channel is that an interest rate cut makes the misallocation towards low NPV projects worse (proposition 4). The misallocation is driven by the term $\Delta PV = \frac{\alpha K}{(1+\alpha)R_F}$, which gets bigger when R_F falls. It is interesting to note that the first derivative of this term is negative whereas the second derivative is positive:

$$\frac{\partial \Delta PV}{\partial R_F} = -\frac{\alpha K}{(1+\alpha){R_F}^2} < 0 \text{ and}$$
$$\frac{\partial^2 \Delta PV}{\partial {R_F}^2} = \frac{2\alpha K}{(1+\alpha){R_F}^3} > 0$$

It follows that an interest rate cut has more bite at low interest rates with the term getting bigger as interest rates approach zero. Hence, this adverse channel is strongest at near zero interest rates and weakest at large interest rates.

As the adverse channel on the production side is strongest near zero interest rates, our approach suggests that a sustained period of low interest rates is structurally damaging to the economy. Interest rates in core advanced economies have been persistently low for about 11 years now. Such persistently low nominal rates are without precedence. At least since 1870, interest rates have never been this low for this long, not even during the great depression. The question of whether monetary policy has been less effective in such a low interest rate environment has been raised in the literature (Hoffman and Borio 2017). Our paper provides a new perspective to this debate.

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