Imperfect reasoning abilities of artificial intelligence models and asset prices (Early stage work)*

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Abstract

Market participants choose the level of costly deployment of artificial intelligence models, such as large language models, to better extract signal about fundamentals from a noisy and multidimensional common data space. The monotonically increasing technology frontier evolves over time but actual adoption depends on the use of scarce resources that influence costs, mimicking constraints in human resources and parallel computing. Participants make decisions based on a 'double global game' with simultaneous higher-order beliefs about asset prices and technology adoption by peers. Similar to the traditional case with assets, participants overinvest in AI because they think others might be doing so, etc. But while this overinvestment in AI reduces the noise about fundamentals, the higher-order beliefs that everyone else also observes lower noise ends up leading to the same theme of overinvestment in the asset as well. If the technology envelope does not include a properly reasoning AI model, which is able to robustly ignore noise about fundamentals, the equilibrium outcome is a self-reinforcing overinvestment both in the asset and in the AI-related resources. In contrast, the emergence of a reasoning model brings the noise to zero and agents coordinate perfectly. JEL codes: C45, C69, C88, C59.

1 Introduction

The increasing capabilities of large language models (LLM) and other artificial intelligence (AI) models create expectations that they can be useful for forecasting and trading (eg, Lopez-Lira and Tang (2023)). But if all market participants expect others to improve their own signal-to-noise ratio by adopting a common technology, a coordination situation with higher-order beliefs similar to the canonical global games arises, in conjunction with the original coordination issue. This paper explores the equilibrium outcome when such a

*This work represents my opinion and not necessarily that of the BIS.

technology evolves according to availability of resources that are also deployed at a cost by market participants to improve their signal.

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2 Literature

This work relates to the literatures on

Coordination with information acquisition. Angeletos and Lian (2016), Szkup and Trevino (2015b), Szkup and Trevino (2015a), Szkup and Trevino (2021). Reshidi et al. (2021) study the individual and collective information acquisition. Technology adoption canonical model D. Frankel and Pauzner (2000). Private aquisition of information (processing), Hellwig and Veldkamp (2009) and Colombo, Femminis, and Pavan (2014). In contrast with that literature, here the AI technology frontier also develops endogenously and responds (negatively) to the resource take-up from technology adoption...

AI in finance, including risks. Danielsson, Macrae, and Uthemann (2022).

3 Model

The model draws from the setup in Szkup and Trevino (2021), with important additions. First, the cost of technology adoption is subject to a flat supply curve, resulting in cost changes that introduce another strategic complementarity. Second, the technology itself evolves over time, and responds to factor prices as well. And third, the process by which AI improves the signal is laid out in more detail to highlight the cases where the technology can absorb more text but cannot yet *reason* about it.

3.1 Setup

The simplest version of the model is as follows.

The state of economic fundamentals is a random variable with normal distribution $\theta \sim N(\mu_\theta, \sigma_\theta^2)$. θ is only observed indirectly by each investor i as a noisy signal, $x_i = \theta + \sigma_i \epsilon_i$. An AI technology $\alpha > 0$ uses $R > 0$ finite specialised resources (eg, AI scientists, data engineers, graphics processing units chips - GPUs, etc) to improve the precision of the signal of the existing data: with $\alpha'_R > 0, \alpha''_R < 0$, and each individual precision defined as $\sigma_i = \sigma/\alpha_i(R)$.

However, unless the AI model can actually reason (as in Araujo, 2024; described further below), very precise signals (low σ_i) also come with the risk of belieavable misinterpretation ("hallucinations") or other forms of "silent mistakes", which bias the investor's perception about fundamentals. Such a problem is of course compounded by the high confidence the investor has in the signal given its acquired low σ_i. This is modelled through a *reasoning filter* ϕ (see Section 4). This function is the identity function if the AI cannot reason and 0 if it can reason. Having $\eta \sim N(0, \sigma_\eta)$ as the baseline level of noise[1] for all private signals, then $\epsilon_i = \eta + \phi(e^{\lambda \alpha_i(R)})$ (λ is an inconsequential scaling constant). Putting all of this together, the private signal about the fundamentals is:

$$x_i = \theta + (\eta + \phi(e^{\lambda \alpha_i(R)}))\sigma/\alpha_i(R) \tag{1}$$

- Two ex ante identical investors, $i \in \{1, 2\}$ choose how much to invest in AI

3.2 Equilibrium in financial and AI investments

After the decisions to invest in AI is taken, the second stage involves an investment in the financial asset. This step resembles a traditional global game (Morris and Shin 2003), but where players choose the precision of their own information (Yang 2015, Szkup and Trevino (2021)).

3.3 Tentative calculations

First, note there is exactly one value of α_i that results in an unbiased private signal.

Definition 3.1 (AI use with minimal bias in private signal)**.** There is only one specific value α^* for which the private signal is the closest to θ in expectation. The subscript is irrelevant because all investors are ex ante similar.

See Definition 3.1.

[1] Reflecting, for example, technology frictions in the production and dissemination of data, or more fundamentally even the sparsity in the actual signal from the manifold hypothesis.

Proof. The first order condition only holds for one value of $\alpha_i > 0$. Isolating α^* in the numerator to the left side yields

$$\frac{d}{d\alpha^*}(\eta + \phi(e^{\lambda\alpha^*}))\sigma/\alpha^* = 0,$$

which can be manipulated to

$$\frac{\lambda e^{\lambda\alpha^*}\sigma}{\alpha} - \frac{e^{\lambda\alpha^*}\sigma}{(\alpha^*)^2} = \frac{\eta\sigma}{(\alpha^*)^2}.$$

Multiplying both sides by $(\alpha^*)^2$ obtains

$$\lambda\alpha^* e^{\lambda\alpha^*}\sigma - e^{\lambda\alpha^*}\sigma = \eta\sigma,$$

which is the same as

$$e^{\lambda\alpha^*}(\lambda\alpha^* - 1) = \eta,$$

and thus the only possible solution is $\alpha^* = 1/\lambda$.

The second order condition obtained by substituting this equality above is positive, confirming that α^* minimises the bias on the signal:

$$\frac{d^2}{d(1/\lambda)^2}(\eta + \phi(e))\sigma\lambda > 0$$

□

The problem is, higher levels of R monotonically increase precision but there is only one level of R that minimises bias in information.

4 Reasoning

Note that ϕ itself is not dependent on the performance of the AI. This is in line with compiling evidence that while the increasing power of AI affords it new abilities, including some that resemble reasoning, ultimately it is even questionable if a robust for of reasoning can be obtained by continuing to scale a technique that involves memorisation rather than actual abstract thinking (LeCun…)

4.1 Equilibrium

Equilibrium D. M. Frankel, Morris, and Pauzner (2003).

5 Statistics

Szkup (2020) show that only the direct effect is important.

6 Conclusions

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