Unleashing the Power of ChatGPT in Finance Research: Opportunities and Challenges

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March 29, 2023

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Abstract

Natural language processing (NLP) technologies, such as ChatGPT, are revolutionizing various fields, including finance research. This article explores the multifaceted potential of ChatGPT as a transformative tool for finance researchers, highlighting the benefits, challenges, and novel insights it can offer to facilitate the research. We demonstrate applications in coding support, theoretical derivation, research idea assistance, and professional editing. A comparison of ChatGPT-3.5, ChatGPT-4, and Microsoft Bing reveals unique features and applicability. By discussing pitfalls and ethical concerns, we encourage responsible AI adoption and a comprehensive understanding of advanced NLP's impact on finance research and practice.

JEL Classification: G00, C89, O33

Keywords: ChatGPT, AI, Finance research

1 Introduction

The rapid advancement of natural language processing (NLP) technologies, such as ChatGPT (Chatbot-based Generative Pre-trained Transformer), has ushered innovation across diverse sectors, including finance (e.g., Dowling and Lucey, 2023; Zaremba and Demir, 2023). As a cutting-edge deep learning artificial intelligence (AI) model, ChatGPT demonstrates remarkable capabilities in various fields and attracts broad attention. Within 100 days after its release on March 10, 2023, ChatGPT has already amassed a staggering 5,600 articles (keyword = ChatGPT) indexed on Google Scholar, underscoring its widespread applicability and academic interests.

This article explored the potential advantages, challenges, and limitations of employing ChatGPT in finance research. We examined its influence on research methodologies, efficiency, and collaboration, while addressing the potential limitations. Using a finance-centric example to demonstrate their relevance in finance research, we conducted a comparative analysis of ChatGPT-3.5, ChatGPT-4, and Microsoft Bing, evaluating their distinct features, strengths, and weaknesses.

Our thorough investigation promoted a more nuanced understanding of the role of advanced NLP technologies like ChatGPT in shaping finance research. It offered valuable insights for researchers, editors, and other stakeholders in the finance community. This exploration encourages informed and responsible AI technology use in finance research, ultimately enhancing the field's quality and impact.

2 The Benefits and Potential Usages

2.1 Empowering Coding Assistance

ChatGPT's coding assistance capabilities through chatbot interaction offer significant benefits, especially for entry-level researchers needing help with programming languages or software. This feature enables efficient learning and code generation to address data analysis challenges. By providing clear step-by-step instructions, researchers can obtain code output from ChatGPT, which can be further revised based on updated requests.

We demonstrate ChatGPT's coding assistance with an option pricing example in Exhibit 1. Here, ChatGPT generates Matlab code for financial analysis, specifically calculating call option implied volatility using the Black and Scholes (1973) model and plotting implied volatility as a function of time to maturity (T) and moneyness (M=S/K). Researchers should critically evaluate the generated code and may employ further iterations with ChatGPT to refine the codes until obtaining the expected results.

[*Exhibit 1 Here*]

ChatGPT's coding assistance has also been documented in other disciplines, such as bioinformatics (e.g., Shen et al., 2023). The chatbot is capable of generating simple code in commonly used finance research programming languages, including Python, R, SAS, Eviews, and Stata. This assistance streamlines the data analysis process, improving productivity and reducing the likelihood of errors. Additionally, it can help entry-level researchers develop coding skills while serving as a personalized assistant for researchers at all levels.

2.2 Formulating and Deriving Theoretical Models

Theoretical modeling is a mainstream area in finance research, where the formulation and derivation of such models are typically challenging but critical for theoretical research. It is common in finance research that it requires years of experience to develop the necessary techniques and strategies in model development and creation. We evaluate ChatGPT's capability to formulate commonly used theoretical models, including those in graduate textbooks and extant literature.

Exhibit 2 showcases the formulation and derivation of an asset pricing model, specifically the option pricing model, using ChatGPT. We first instructed the chatbot to generate the Black and Scholes (1973) model, a fundamental option pricing model taught in Ph.D. courses. ChatGPT efficiently derived the option price step-by-step.[1] Upon resetting the attempts, ChatGPT consistently demonstrated successful derivation of the Black-Scholes option pricing formula, with some variations in the steps. We then extended the Black-Scholes model to include stochastic volatilities, and ChatGPT provided the derivation of the Heston (1993) model. It generated the partial differential equation (PDE) for an option price with stochastic volatility but faced difficulty solving the PDE. After multiple attempts, it provided the expected solution, but the solution did not easily converge, as discussed in Prompt 2 of Exhibit 2.

[*Exhibit 2 Here*]

While the literature contains various models and their extensions, collecting and organizing information can be time-consuming and challenging. However, with the help of ChatGPT, this task can be completed efficiently. ChatGPT's line-by-line explanation of the model not only aids in gathering information but also enhances the researcher's understanding of the material. This function is a valuable resource for research. It provides a solid foundation for developing innovative theoretical models, especially for Ph.D. students and junior researchers who may be less familiar with the research area.

2.3 Unlocking Innovation in Research Ideas

ChatGPT can serve as a valuable tool for finance researchers seeking to generate fresh insights and ideas (Dowling and Lucey, 2023). By engaging ChatGPT with specific questions or topics, researchers can formulate new hypotheses based on prior findings and identify emerging themes. We demonstrate ChatGPT's innovative potential with an example requesting a novel hypothesis related to "Climate Risk and Asset Pricing."

[1] We may further prompt ChatGPT to provide a detailed derivation in solving the PDE to obtain the option pricing formula. Due to the space constraint of this paper, we have not reported these results. However, they are available upon request.

In Exhibit 3, ChatGPT proposes a hypothesis that incorporating climate risk mitigation strategies into a firm's operations can reduce its cost of capital and positively influence asset pricing. Notably, ChatGPT introduces the concept of a firm's cost of capital as an investigation channel without any provided information. Finance researchers can assess the research topic's merit by examining the economic theory, previous literature findings, and data availability. It is worth mentioning that the model does not always provide the same answers each time.

[*Exhibit 3 Here*]

Utilizing ChatGPT as a source of inspiration, researchers can leverage existing information to unlock new perspectives and generate innovative ideas, enhancing their work's quality and relevance in the evolving finance field. With access to cutting-edge technologies and data analytics tools, researchers can better understand complex financial phenomena and identify new analysis opportunities. ChatGPT is a valuable resource for researchers seeking to push finance research boundaries and drive progress.

2.4 Textual Information Processing, Professional Editing, and Translation

ChatGPT offers the ability to quickly analyze large amounts of textual data from various sources, such as news articles and social media posts (Dai et al., 2023; Lund and Wang, 2023). This feature allows finance researchers to process textual information more efficiently than traditional methods and identify patterns that may be difficult to discern using statistical methods. However, some ChatGPT responses may be imprecise, necessitating human evaluation for accuracy.

ChatGPT also provides professional editing and translation services, which are highly beneficial to finance researchers. Professional editing helps researchers refine their work to meet quality and professionalism standards, with comprehensive feedback on structure, tone, and style (Hosseini et al., 2023). This feature is particularly useful for non-native English speakers facing language barriers or unfamiliar with writing conventions. In this manuscript, we utilized ChatGPT to enhance the writing quality.

The translation capabilities of ChatGPT are invaluable for making work accessible and comprehensible to a global audience. This function benefits those who need to translate their work for international readers and those operating in multilingual contexts. Most importantly, ChatGPT's translation capabilities can foster international collaboration on cross-cultural or global projects among researchers with diverse language backgrounds, benefiting the entire academic community.

3 Challenges and Limitations

3.1 Reliability and Accuracy

Despite ChatGPT's potential benefits for finance research, challenges and limitations related to reliability and accuracy exist. ChatGPT generates plausible text, but it may not always be accurate or reliable, as discussed in previous sections (Alkaissi and McFarlane, 2023; Tsigaris and Teixeira da Silva, 2023; Cascella et al., 2023). Consequently, finance researchers must exercise caution when interpreting ChatGPT-generated results and validate their findings using traditional methods and literature reviews.

To illustrate, we asked ChatGPT to identify relevant literature on "Climate Risk and Asset Pricing" and generate article summaries, as displayed in Exhibit 4. Although the papers provided may be limited and not include the most recent publications, they can serve as a starting point for further explorations. It is worth mentioning that the model does not always provide the same section of answers. Researchers must verify the AI-generated information as it may not always be accurate or reliable. Consequently, finance researchers must exercise caution when interpreting ChatGPT-generated results and ensure that they validate their findings using traditional statistical methods and comprehensive literature reviews.

[*Exhibit 4 Here*]

3.2 Plagiarism or Falsification

Finance researchers using ChatGPT must be vigilant about potential risks of plagiarism or falsification. ChatGPT's outputs may not always be supported by pertinent literature, and generated factual statements or arguments could be drawn from sources without proper attribution (Helgesson and Eriksson, 2015). Plagiarism, using ideas, words, or concepts without adequate attribution, is strictly prohibited in academia. Relying on ChatGPT's ideas without due credit is also a severe violation of ethical standards (González-Padilla, 2022; Anders, 2023; van Dis et al., 2023).

To mitigate ethical concerns, some researchers propose AI output detectors in the editorial process (Frye, 2022; Gao et al., 2022; Khalil and Er, 2023). These detectors can identify and flag AI-generated content, ensuring rigorous scientific standards are maintained and addressing ethical issues associated with AI-generated research outputs. By adopting a responsible approach to using ChatGPT in finance research, academics can preserve the integrity of their work while benefiting from AI technology's cutting-edge capabilities.

3.3 Incapacity in Causal, Multi-Hop, and Analogical Reasoning

ChatGPT exhibits shortcomings in tasks requiring logical thinking, non-textual reasoning, and commonsense reasoning (Bang et al., 2023; Borji, 2023), stemming from the AI model's training data limitations (Strubell et al., 2019). The complexity of data used in finance research often surpasses the information encountered during ChatGPT's training.

Finance research demands a high degree of causal, multi-hop, and analogical reasoning, which is not ChatGPT's strength. The complexity of economic theories and identification strategies can exceed the AI model's capacity for effective analysis. Researchers must be cautious when relying on ChatGPT for tasks requiring advanced reasoning abilities, ensuring accuracy and validity in their work by making informed decisions about using AI technology.

3.4 Inadequacy in Handling Licensed or Proprietary Data

ChatGPT's ability to work with licensed or proprietary data, often used by finance researchers, is limited. Its training is primarily based on publicly available data, catering to general public needs, and its applicability in specialized research scenarios involving proprietary or confidential data remains underdeveloped (Cascella et al., 2023). Although ChatGPT aims to avoid biases towards specific data types or sources, its proficiency in handling licensed or proprietary data is restricted. Consequently, finance researchers may face challenges integrating ChatGPT with their unique datasets.

3.5 Copyright and Authorship

Finance researchers must consider copyright and authorship issues when using ChatGPT in academic writing. While ChatGPT significantly contributes to a paper (Shen et al., 2023), its input cannot equal intellectual input from a human author. Hosseini et al. (2023) argue against claiming originality for ChatGPT-generated content. Additionally, Yeo-Teh and Tang (2023), da Silva (2023), Stokel-Walker (2023), and Thorp (2023) contend that ChatGPT should not be listed as an author, as it cannot fulfill standard authorship criteria or assume ethical or legal responsibilities. By clearly distinguishing ChatGPT's and human authors' roles and contributions, finance researchers can maintain high ethical standards while leveraging ChatGPT's potential.

4 Comparing the Responses of ChatGPT-3.5, ChatGPT-4, and Microsoft Bing Chat

The release of ChatGPT-3.5 on November 30, 2022, and the subsequent launch of GPT-4 on March 14, 2023, have brought about significant advancements in AI language models. GPT-4, exclusively available to ChatGPT Plus users, is believed to offer more reliable, creative, and nuanced responses than its predecessor, ChatGPT-3.5. In addition, on February 7, 2023, Microsoft introduced an updated version of its Bing search engine that incorporates OpenAI's ChatGPT-4 model, providing users access to more recent web sources and information beyond 2021. These models have similar language architectures but differ in ways, making their comparison in finance research insightful.

We asked each model: "In what ways do adjustments in the Federal Reserve's target interest rates, specifically rate increases, impact the operations of commercial banks, and through which transmission channels do these effects manifest?" We posed the question three times to each AI, generating responses shown in Exhibit 5.

ChatGPT-3.5 displayed more significant variances in identifying the transmission channels through which interest rate increases impact commercial banks, while ChatGPT-4 provided more consistent and comprehensive presentations of these channels. ChatGPT-4 responses also appeared more relevant to bank operations, reflecting its enhanced ability to generate contextually appropriate content.

On the other hand, Microsoft Bing Chat produced responses that seemed to be sourced from other websites, resembling summaries of web pages that appeared on the first page of search engine results. While this approach may provide valuable information, it may not always yield the most in-depth or nuanced insights.

Detailed feedback is available in the online appendix. These comparisons highlight the need to understand each AI model's strengths and limitations in finance research. Considering its unique characteristics, researchers should select the appropriate AI model for a specific task.

[*Exhibit 5 Here*]

5 New Insights

ChatGPT has had a transformative impact on scientific research and education, including finance. Its diverse potential applications span automated essay grading, personalized learning, curriculum development, and tutoring support. ChatGPT enables innovative approaches to financial research, but it should be integrated responsibly as a supplementary tool that complements existing techniques. This balanced approach ensures researchers maintain robust analytical skills while benefiting from ChatGPT's efficiency and advanced capabilities.

Another critical aspect is fostering interdisciplinary collaboration. ChatGPT's capacity to process and synthesize information from various fields promotes an environment where researchers from different disciplines can collaborate on complex issues. This multidisciplinary collaboration can drive innovative solutions and propel the field forward.

By responsibly utilizing ChatGPT's capabilities, finance professionals and academics can capitalize on knowledge discovery and collaboration opportunities. As researchers explore ChatGPT's potential alongside traditional methods, they will play an instrumental role in shaping the ongoing evolution of finance academia.

6 Conclusion

Incorporating ChatGPT in finance research opens a realm of opportunities, but its adoption also comes with challenges and limitations, including concerns regarding reliability and accuracy. Researchers must be mindful of these limitations and use ChatGPT responsibly to harness its potential benefits. They should consider ethical implications, implement measures to counter biases and foster interdisciplinary collaboration for effective AI application and valuable insights generation.

Approaching ChatGPT cautiously, researchers should remain vigilant of potential pitfalls, meticulously verify generated information, and adhere to ethical guidelines. This approach enables them to harness AI's potential while upholding high academic standards. By responsibly embracing ChatGPT, finance researchers can shape the future of academia, expand our understanding of finance, and explore its societal impacts. This collaborative effort ultimately leads to deeper insights, innovative solutions, and broader perspectives in finance research.

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Exhibit 1: Coding Assistance through ChatGPT

In this exhibit, we request ChatGPT to generate a Matlab code for an option pricing analysis. The "Prompt" refers to the request made by the authors, while the "Response" refers to the feedback provided by ChatGPT-4. The authors then provide an "Assessment" of the quality and accuracy of the response.

<table>
<tr><td rowspan="6">Prompts</td><td colspan="2">Define chatbot's behaviors</td></tr>
<tr><td colspan="2">Act as an experienced finance research specialized in option pricing and proficient in Matlab, you will write code with number of lines as minimal as possible. Input variables will be input manually. Reply "Input received" when receive input variables. Details of data analysis will be {like this}. Reply "Analysis request received" when receive text within {}, explain the text, followed by generating the code. Reset the thread when asked to. Reply "Yes" if understood.</td></tr>
<tr><td colspan="2">Input variables</td></tr>
<tr><td colspan="2">% Inputs:
S0=100;
r=5/100;
T=[.25 .25 .25 .25 .25 .5 .5 .5 .5 .5 .75 .75 .75 .75 .75];
K=[90 95 100 105 110 90 95 100 105 110 90 95 100 105 110];
CallPrice=[13.33 9.24 6.15 4.22 3.26 15.84 11.67 8.55 6.62 5.75 17.79 13.50 10.34 8.43 7.68];</td></tr>
<tr><td colspan="2">Details of data analysis</td></tr>
<tr><td colspan="2">Request 1:
{Calculate call option implied volatility for each call option price and return a vector of implied volatility using Black and Scholes (1973) model}

Request 2:
{Use the implied volatility calculated from the previous request, plot the implied volatility as a function of time to maturity (T) for K=100 (ATM options)}

Request 3:
{Use the implied volatility calculated from the previous request, plot the implied volatility as a function of moneyness (M=S/K) for T=0.25}</td></tr>
<tr><td>Response:</td><td>Request 1</td><td>Code

% Implied volatility calculation using Newton-Raphson method
tol = 1e-6; % tolerance level
max_iter = 100; % maximum number of iterations
sigma = zeros(size(CallPrice)); % initialize vector of implied volatilities

for i = 1:length(CallPrice)
 % initial guess for implied volatility
 sigma_n = 0.2;

 % iterate using Newton-Raphson method
 for j = 1:max_iter
 d1 = (log(S0/K(i)) + (r + sigma_n^2/2)*T(i)) / (sigma_n * sqrt(T(i)));
 d2 = d1 - sigma_n * sqrt(T(i));
 C = S0 * normcdf(d1) - K(i) * exp(-r*T(i)) * normcdf(d2);
 Cprime = S0 * normpdf(d1) * sqrt(T(i));
 sigma_n = sigma_n - (C - CallPrice(i)) / Cprime;

 % check for convergence
 if abs(C - CallPrice(i)) < tol
 break
 end</td></tr>
</table>

```
 end

 % assign final value of implied volatility to vector
 sigma(i) = sigma_n;
end
```

Result

```
Sigma = [0.333225444490325      0.290949350388882      0.278012884641841
         0.289917614414093      0.323097686316413      0.316119443315466
         0.273857623822640      0.260552247728689      0.272401715021651
         0.305917792662252      0.302698180099093      0.260431118754392
         0.247342202118206      0.259177226411055      0.292774953928529]
```

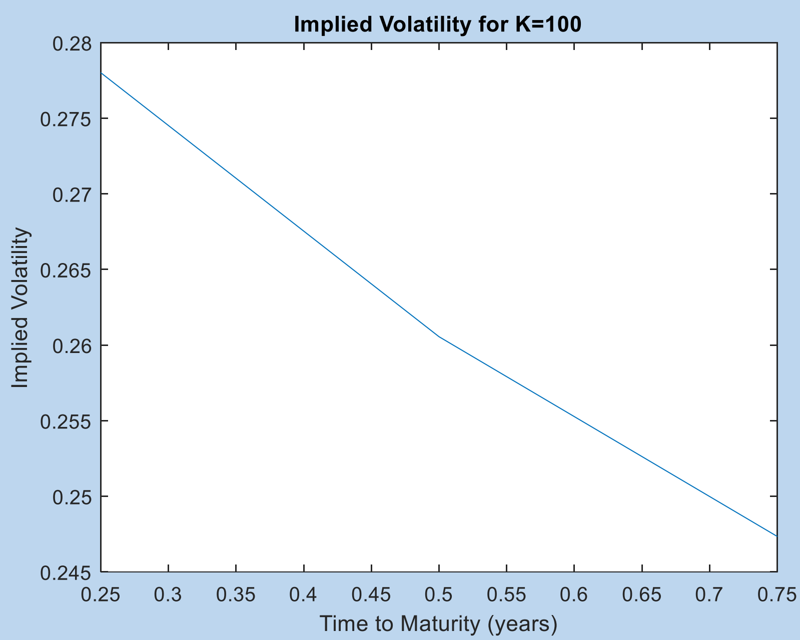
Request 2

Code

```
% Extract implied volatility for K=100
sigma_K100 = sigma(K == 100);

% Plot implied volatility as a function of time to maturity for K=100
plot(T(K == 100), sigma_K100)
xlabel('Time to Maturity (years)')
ylabel('Implied Volatility')
title('Implied Volatility for K=100')
```

Result



Request 3

Code

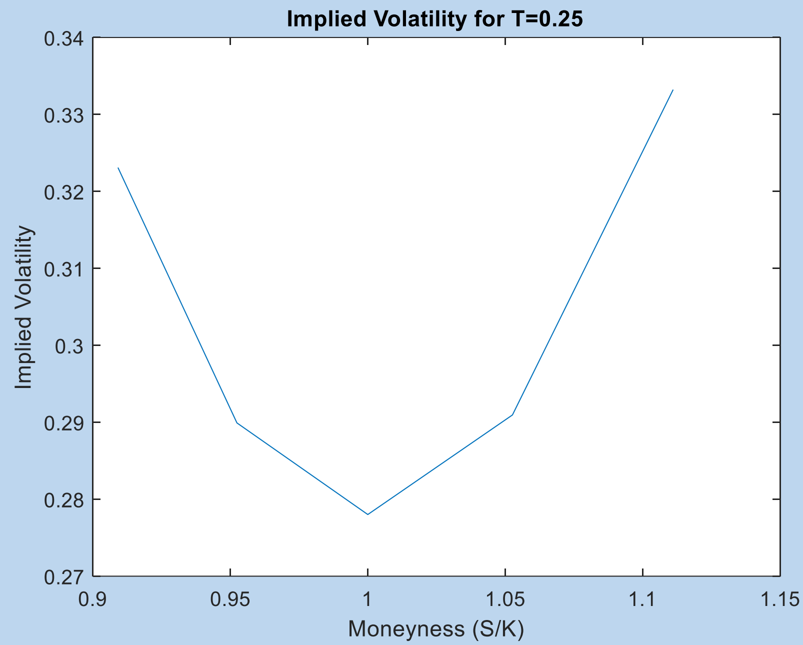
```
% Extract implied volatility for T=0.25
sigma_T025 = sigma(T == 0.25);

% Calculate moneyness values
```

```
M = S0 ./ K;

% Plot implied volatility as a function of moneyness for T=0.25
plot(M(T == 0.25), sigma_T025(T == 0.25))
xlabel('Moneyness (S/K)')
ylabel('Implied Volatility')
title('Implied Volatility for T=0.25')
```

Result



Assessment:

ChatGPT-4 is capable of generating simple codes in various programming languages as per the requested prompt. The reviewer can run the code using appropriate programming software and verify the results. In case of any adjustments or revisions, the prompts can be reset, or updated requests can be sent.

Generally, it may take a few iterations to complete an empirical task. To facilitate the debugging process, it is recommended to request and verify a task step-by-step.

Exhibit 2: Deriving Theoretical Models Using ChatGPT

This exhibit demonstrates how ChatGPT provides a step-by-step derivation of option pricing models. The "Prompt" refers to the request made by the authors, while the "Response" refers to the feedback provided by ChatGPT-4. The authors then provide an "Assessment" of the quality and accuracy of the response.

Prompt 1:

Act as a finance professor, show the step-by-step derivation of the Black-Scholes model.

Response 1:

The Black-Scholes model is a mathematical formula used to calculate the theoretical value of a European call option, assuming that the underlying stock price follows a geometric Brownian motion. The derivation of the model involves several mathematical concepts, including stochastic calculus and partial differential equations. Here are the main steps in the derivation:

1. Assume that the price of the underlying asset follows a geometric Brownian motion, which is described by the following stochastic differential equation:

$dS(t) = \mu S(t)dt + \sigma S(t)dW(t)$

where $S(t)$ is the price of the underlying asset at time t, μ is the expected return of the asset, σ is the volatility of the asset, and $dW(t)$ is a Wiener process or Brownian motion, which represents the randomness or uncertainty in the asset's price movements.

2. Use Ito's lemma to derive the differential equation for the option price. Assume that the option price is a function of the underlying asset price and time, denoted as V(S,t). By applying Ito's lemma to this function, we obtain the following differential equation:

$dV = (\partial V/\partial t)dt + (\partial V/\partial S)dS + (1/2)(\partial^2V/\partial S^2)(dS)^2$

3. Use the risk-neutral valuation principle to price the option. The risk-neutral valuation principle states that the expected return of any financial asset should be equal to the risk-free rate of return. In other words, the expected value of the asset's future cash flows, discounted at the risk-free rate, should equal its current market price. We can apply this principle to price the option by assuming that the option price is equal to the discounted expected payoff of the option under the risk-neutral probability measure.
4. Derive the Black-Scholes partial differential equation (PDE) by substituting the geometric Brownian motion equation and the option price differential equation into the risk-neutral valuation formula. After some algebraic manipulation, we obtain the following PDE:

$(\partial V/\partial t) + (1/2)\sigma^2S^2(\partial^2V/\partial S^2) + rS(\partial V/\partial S) - rV = 0$

where r is the risk-free interest rate.

5. Use the boundary conditions to solve the PDE and derive the Black-Scholes formula for the European call option. The boundary conditions for the European call option are $V(S,T) = \max(S-K,0)$ and $V(S,0) = 0$, where T is the time to maturity and K is the strike price of the option. By solving the PDE under these boundary conditions, we obtain the following formula for the European call option price:

$C(S,t) = S\Phi(d1) - Ke^{-r(T-t)}\Phi(d2)$

where $d1 = [\ln(S/K) + (r + \sigma^2/2)(T-t)] / (\sigma\sqrt{(T-t)})$ and $d2 = d1 - \sigma\sqrt{(T-t)}$, and $\Phi(.)$ is the cumulative distribution function of the standard normal distribution.

That's a brief overview of the steps involved in the derivation of the Black-Scholes model. It's worth noting that there are several assumptions and limitations of the model, and it's important to understand these before applying the model in practice.

Assessment:

ChatGPT successfully derived the partial differential equation (PDE) and price formula for the Black-Scholes option pricing model. Sending the prompt multiple times in a different window may result in a variation in response. Nevertheless, it is important to note that the PDE and option price consistently converge to the same formulas.

Prompt 2:

Build upon the Black-Sholes option pricing model, derive an option pricing model with stochastic volatility.

Response 2:

The Black-Scholes model is a popular framework for option pricing that assumes the volatility of the underlying asset is constant over time. However, in reality, volatility can be quite variable, and it can be difficult to accurately predict its future values. To account for this, we can introduce stochastic volatility into the model.

One of the most popular models for stochastic volatility is the Heston model. The Heston model assumes that the price of the underlying asset follows a geometric Brownian motion, as in the Black-Scholes model, but the volatility of the asset is itself a stochastic process, following a square-root diffusion equation.

The main steps in the derivation of the Heston model are as follows:

1. Assume that the price of the underlying asset follows a geometric Brownian motion, as in the Black-Scholes model:

dS(t) = μS(t)dt + √v(t)S(t)dW1(t)

where v(t) is the stochastic volatility process, W1(t) is a Wiener process, and all other symbols are as defined in the Black-Scholes model.

2. Assume that the stochastic volatility process follows a square-root diffusion equation:

dv(t) = κ(θ - v(t))dt + σ√v(t)dW2(t)

where κ is the mean reversion speed, θ is the long-run average volatility, σ is the volatility of the volatility process, W2(t) is another Wiener process that is correlated with W1(t), and all other symbols are as defined above.

3. Use Ito's lemma to derive the differential equation for the option price. By applying Ito's lemma to the option price function, V(S,t), we obtain the following differential equation:

dV = (∂V/∂t)dt + (∂V/∂S)dS + (∂V/∂v)dv + (1/2)(∂^2V/∂S^2)(dS)^2 + (1/2)(∂^2V/∂v^2)(dv)^2 + (∂^2V/∂S∂v)dSdv

4. Use the risk-neutral valuation principle to price the option. Similar to the Black-Scholes model, we assume that the option price is equal to the discounted expected payoff of the option under the risk-neutral probability measure.
5. Derive the Heston PDE by substituting the asset price and volatility processes and the option price differential equation into the risk-neutral valuation formula. After some algebraic manipulation, we obtain the following PDE:

(∂V/∂t) + (1/2)S^2(∂^2V/∂S^2) + (r-q)S(∂V/∂S) + (κ(θ-v)∂V/∂v) + (1/2)(σ^2v)(∂^2V/∂v^2) + ρσSv(∂^2V/∂S∂v) - rV = 0

where ρ is the correlation between the two Wiener processes, and all other symbols are as defined above.

6. Use the boundary conditions to solve the PDE and derive the Heston formula for the European call option. The boundary conditions for the European call option are V(S,T) = max(S-K,0) and V(S,0) = 0. By solving the PDE under these boundary conditions, we obtain the following formula for the European call option price:

C(S,t) = S

Assessment:

ChatGPT was able to successfully derive the PDE for an option pricing model with stochastic volatility and produced results up to step 6. However, it stopped in step 6, likely due to the complexity of the equations involved. After multiple attempts by resubmitting the request in separate windows, ChatGPT produced results that were sometimes incomplete (similar to the one shown above), sometimes incorrect (2a), and occasionally provided a closer solution to Heston (1993) (2b).

Prompt 2a:

The above answers are not complete. Please continue to solve the PDE and get the European call option price formula.

Response 2a:

My apologies for the oversight. Here is the continuation of the derivation to obtain the Heston formula for the European call option:

6. Use the boundary conditions to solve the PDE and derive the Heston formula for the European call option. The boundary conditions for the European call option are V(S,T) = max(S-K,0) and V(S,0) = 0. By solving the PDE under these boundary conditions, we obtain the following formula for the European call option price:

C(S,t) = SΦ(d1) - Ke^{-r(T-t)}Φ(d2)

where

d1 = [ln(S/K) + (r-q + 1/2v0)(T-t)] / √v0(T-t) d2 = d1 - √v0(T-t) v0 = the initial volatility level Φ(.) = the standard normal cumulative distribution function K = the strike price r = the risk-free interest rate q = the continuous dividend yield on the underlying asset.

Note that the Heston formula for the European call option is similar to the Black-Scholes formula, but with a modified volatility term that depends on the stochastic volatility process. The key difference is that the volatility term in the Heston model is stochastic, while in the Black-Scholes model, it is assumed to be constant. The Heston model can be used to capture some of the complex dynamics of asset prices and volatility in financial markets.

Prompt 2b:

Build upon Black-Sholes option pricing model, derive a option pricing formula with stochastic volatility.

Response 2b

Sure, here's a step-by-step derivation of an option pricing formula with stochastic volatility based on the Black-Scholes model with a geometric Brownian motion (GBM) model for the stock price and a Heston model for the volatility:

Step 1: Define the Black-Scholes-Heston Model The Black-Scholes-Heston model assumes that the stock price follows a GBM process and the volatility follows a Heston model. The stochastic differential equations for the stock price and the volatility are:

$dS = rS\, dt + \mathrm{sqrt}(v)\, S\, dW1$

$dv = \kappa (\theta - v)\, dt + \sigma\, \mathrm{sqrt}(v)\, dW2$

where S is the stock price, r is the risk-free interest rate, v is the volatility, κ is the mean reversion speed, θ is the long-term variance, σ is the volatility of the volatility, W1 and W2 are two Wiener processes with correlation ρ.

Step 2: Derive the Characteristic Function To price options using the Black-Scholes-Heston model, we need to derive the characteristic function of the logarithm of the stock price, denoted by ϕ(u, t). The characteristic function is given by the solution to the following partial differential equation:

$\partial\phi/\partial t + (1/2)\, v\, S^2\, \partial^2\phi/\partial S^2 + (r - iu)u\, \partial\phi/\partial u + (\kappa (\theta - v) / \sigma^2)\, [(a - b\rho iu) - d]\, \phi = 0$

where i is the imaginary unit, $a = \kappa\theta$, $b = \kappa + \lambda - \rho\, \sigma$, and $d = \mathrm{sqrt}(b^2 - 4\kappa\lambda)$ is the discriminant of the characteristic equation.

The solution to this partial differential equation is given by:

$\phi(u, t) = \exp[(iu - r)\, t + (a / \sigma^2)\, [(b - \rho iu) - d]\, t / (2\kappa) - (S0 / \sigma^2)\, F(t, u)]$

where S0 is the initial stock price and F(t, u) is a complex-valued function that can be expressed in closed form or approximated numerically.

Step 3: Calculate the Option Price The price of a European call option with strike price K and expiration time T is given by:

$C(S0, t) = S0\, P1 - K \exp(-r(T - t))\, P2$

where

$P1 = (1/2) + (1/2)\, (1/\pi) \int_0^\infty \mathrm{Re}[(e^{-iu \ln(K)}\, \phi(u - i(t - T), t)) / (iu\, \phi(-iu, t))]\, du$

$P2 = (1/2) + (1/2)\, (1/\pi) \int_0^\infty \mathrm{Re}[(e^{-iu \ln(K)}\, \phi(u - i(t - T), T)) / (iu\, \phi(-iu, T))]\, du$

and Re[.] denotes the real part of a complex number.

Assessment:

ChatGPT demonstrates a solid understanding of the Black-Scholes option pricing models and is capable of generating a systematic and precise step-by-step derivation. However, it has been observed to face challenges in generating consistent results for more complicated models in the literature, such as the stochastic volatility model or jump models. Even with this limitation, the feature of consistently deriving Black-Scholes option pricing models is particularly helpful for Ph.D. students or junior researchers who are less familiar with the models and research areas. Furthermore, researchers can ask the chatbot to provide more detailed explanations or derivations between steps, as discussed in footnote 1.

Exhibit 3: New Insights and Ideas with the Assistance of ChatGPT

The "Prompt" refers to the request made by the authors, while the "Response" refers to the feedback provided by ChatGPT-4. The authors then provide an "Assessment" of the quality and accuracy of the response.

Prompt:

As an experienced finance researcher, you will develop a new hypothesis on "Climate Risk and Asset Pricing". The empirical research topic should be based on the relevant literature and contribute to the literature.

Response:

Based on the relevant literature, I propose the following hypothesis for a new empirical research topic on "Climate Risk and Asset Pricing":

Hypothesis: The integration of climate risk mitigation strategies in a firm's operations can lead to a reduction in the firm's cost of capital and positively affect its asset pricing.

Rationale: Previous research has primarily focused on the impact of climate risk exposure on asset pricing and has established that investors demand a carbon risk premium for holding companies with high carbon emissions. However, there is limited research on how firms that actively integrate climate risk mitigation strategies into their operations impact their cost of capital and, subsequently, asset pricing.

This new hypothesis aims to explore the potential benefits for firms that adopt climate risk mitigation strategies, such as reducing greenhouse gas emissions, investing in renewable energy, implementing energy-efficient technologies, and increasing supply chain resilience. The study will investigate whether these strategies can lead to a reduction in a firm's cost of capital, as investors may perceive these firms as less risky, and whether this effect translates into higher asset prices.

To test this hypothesis, the research will:

1. Identify a sample of firms with varying levels of climate risk mitigation strategies and categorize them based on the extent of their efforts.
2. Measure the cost of capital for these firms using standard financial metrics, such as the weighted average cost of capital (WACC).
3. Examine the relationship between the level of climate risk mitigation efforts and the cost of capital while controlling for other relevant factors, such as industry, firm size, and financial leverage.
4. Investigate the impact of the cost of capital on asset pricing by analyzing stock returns, valuations, and other relevant financial performance indicators.

If the hypothesis is supported by the empirical results, this research could contribute to the literature by showing the potential financial benefits of adopting climate risk mitigation strategies, which may encourage firms to become more proactive in their efforts to address climate risk. Additionally, this study could help investors identify firms with lower climate risk exposure, potentially leading to more sustainable investment portfolios.

Assessment:

ChatGPT provides a hypothesis that aims to determine how firms that actively integrate climate risk mitigation strategies into their operations impact their cost of capital and, subsequently, asset pricing.

The hypothesis seems reasonable and can serve as a starting point for a research project. Again, the researcher must dig deep into the literature and consider the topic's feasibility.

Exhibit 4: Literature Review with the Assistance of ChatGPT

The "Prompt" refers to the request made by the authors, while the "Response" refers to the feedback provided by ChatGPT-4. The authors then provide an "Assessment" of the quality and accuracy of the response.

Prompt:

As an experienced finance researcher, you will identify relevant literature on "Climate Risk and Asset Pricing" by generating summaries of articles or providing a list of relevant papers published in top-tier peer-reviewed journals in finance.

Response:

Here's a list of relevant papers on "Climate Risk and Asset Pricing" published in top-tier peer-reviewed finance journals. I have provided a brief summary for each paper to give you an idea of their content:

1. Bolton, P., & Kacperczyk, M. (2020). Do Investors Care About Carbon Risk? The Journal of Finance, 75(6), 2705-2756.
   - This paper investigates the effect of carbon emissions on the pricing of financial assets. The authors find evidence that investors require a carbon risk premium for holding companies with high carbon emissions, which leads to lower valuations for high-emission firms.

2. Hong, H., Li, F.W., & Xu, J. (2019). Climate Risks and Market Efficiency. The Journal of Econometrics, 208(1), 265-281.
   - The authors explore the impact of climate risks on market efficiency. They find that markets partially price climate risk and show that weather-related information is incorporated into stock prices, with industries that are more exposed to climate risks exhibiting stronger effects.

3. Pastor, L., & Stambaugh, R.F. (2019). Liquidity Risk and Climate Risk in Asset Pricing. The Review of Financial Studies, 32(11), 4301-4345.
   - This paper analyzes the joint role of liquidity risk and climate risk in asset pricing. The authors provide evidence that both types of risks are priced in financial markets, and that the two risks interact with each other, as liquidity risk amplifies the impact of climate risk on asset prices.

4. Giglio, S., Maggiori, M., Stroebel, J., & Utkus, S. (2021). Climate Change and Long-Run Discount Rates: Evidence from Real Estate. The Journal of Finance, 76(3), 1049-1099.
   - This study focuses on the effect of climate change on long-run discount rates, using real estate data. The authors find that climate change affects discount rates through two channels: increasing uncertainty and altering risk preferences, leading to an upward shift in the term structure of discount rates.

5. Engle, R.F., Giglio, S., Kelly, B., Lee, H., & Stroebel, J. (2020). Hedging Climate Change News. The Review of Financial Studies, 33(3), 1184-1216.
   - The authors develop a model for hedging climate change news by considering the interaction between climate change news and financial market returns. They propose a new measure of climate risk exposure and find that climate news has significant effects on asset prices.

6. Ilhan, E., Sautner, Z., & Vilkov, G. (2021). Carbon Tail Risk. The Review of Financial Studies, 34(6), 2756-2807.
   - This paper examines the impact of carbon tail risk on asset prices. The authors find that carbon-intensive firms face higher tail risk and are more exposed to climate regulation shocks, which leads to a negative relationship between carbon intensity and expected stock returns.

These papers provide a comprehensive overview of the current research on climate risk and asset pricing, and they can serve as a starting point for your research on this topic.

Assessment:

ChatGPT sometimes makes up a response that is not accurate or reliable. For instance,

- The 1st article is not published in *The Journal of Finance*. The correct citation should be: Bolton, P., & Kacperczyk, M. (2021). Do investors care about carbon risk?. *Journal of Financial Economics*, 142(2), 517-549.
- The 3rd article does not exist.
- The 4th article is not published in *The Journal of Finance*. The correct citation should be: Giglio, S., Maggiori, M., Rao, K., Stroebel, J., & Weber, A. (2021). Climate change and long-run discount rates: Evidence from real estate. *The Review of Financial Studies*, 34(8), 3527-3571.
- The 6th article is not published in Volume 34, *Issue 6*. It is on *Issue 3*. The correct citation should be: Ilhan, E., Sautner, Z., & Vilkov, G. (2021). Carbon tail risk. *The Review of Financial Studies*, 34(3), 1540-1571.

ChatGPT helps provide a list of relevant papers on a particular topic. But the researcher should exercise caution by verifying whether the text generated by ChatGPT may not always be accurate or reliable. It is vital to verify the information provided by AI-generated responses.

Exhibit 5: Comparing the Responses of ChatGPT-3.5, ChatGPT-4, and Microsoft Bing Chat

This exhibit presents the responses of ChatGPT-3.5, ChatGPT-4, and Microsoft Bing to the same prompt, highlighting their differences. The "Prompt" is the request written by the authors, while the "Summary - Response" represents a summary completed by the authors based on the feedback provided entirely by ChatGPT-3.5, ChatGPT-4, and Microsoft Bing, respectively. The "Assessment" is completed by the authors. Detailed feedback from each AI response is available in the online appendix.

Prompt:
In what ways do adjustments in the Federal Reserve's target interest rates, specifically rate increases, impact the operations of commercial banks, and through which transmission channels do these effects manifest?
ChatGPT-3.5
Response 1:
When the Federal Reserve increases its target interest rates, it impacts commercial banks' operations by affecting their funding costs, deposit levels, and loan demand. These effects are transmitted through various channels, including the federal funds rate, deposit competition, and shifts in loan demand.
Response 2:
Interest rate increases can influence banks' profitability, lending activities, and customer behavior. The primary transmission channels through which these effects occur include the net interest margin, demand for loans, asset prices, and consumer behavior.
Response 3:
When the Fed raises its target interest rate, the cost of borrowing money increases, making it more expensive for banks to borrow from the Fed or other financial institutions. Consequently, this can lead to changes in lending rates, borrowing costs, deposit rates, profitability, and asset prices. These impacts can manifest through various transmission channels, such as the lending, balance sheet, expectations, and exchange rate channels.
ChatGPT-4
Response 1:
Increases in the Federal Reserve's target interest rates can affect banks through various transmission channels, including cost of funds, net interest margin, balance sheet, capital, bank lending, expectations, and exchange rate channels. These channels influence banks' profitability, lending activities, and overall risk appetite, ultimately impacting the broader economy.
Response 2:
Increases in the Federal Reserve's target interest rates can impact banks' operations through various transmission channels, including the cost of funds, net interest margin, balance sheet, capital, bank lending, expectations, and exchange rate channels, affecting their lending activities, profitability, balance sheets, and exposure to risks.
Response 3:
Increases in the Federal Reserve's target interest rates can affect banks' operations through multiple channels, including cost of funds, net interest margins, deposit rates, asset quality, capital and liquidity positions, monetary policy transmission, and competition. The overall impact on banks depends on the magnitude of the rate change, individual bank characteristics, and the broader economic environment.
Microsoft Bing (conversation style: more balanced)
Response 1:
When interest rates increase, banks tend to raise their lending rates, reducing consumer and business borrowing—this decrease in borrowing results in lower profits for businesses and reduced employment opportunities. The effects of interest rate increases on commercial banks manifest through several transmission channels, such as the net interest margin, balance sheet, and bank lending channels.

Learn more: 1. investopedia.com2. americanexpress.com3. nytimes.com
Response 2:
When interest rates increase, borrowing money becomes more expensive for banks, leading to higher interest rates on consumer loans and credit cards. The effects of rate increases manifest through several transmission channels, including changes in bank lending behavior, asset prices, exchange rates, and expectations about future inflation and economic growth. Learn more: 1. investopedia.com2. forbes.com3. hlcequity.com4. finance.yahoo.com5. seekingalpha.com6. cnet.com+3 more
Response 3:
One of the most significant effects of interest rate increases is that banks are more expensive to borrow money from the Federal Reserve. This increase in borrowing costs can decrease the money banks have available to lend to their customers. Interest rate increases can affect commercial banks through their profitability, and several transmission channels include changes in bank lending behavior, consumer spending patterns, and the overall health of the economy. Learn more: 1. americanexpress.com2. investopedia.com3. nytimes.com
Assessment:
The responses provided by ChatGPT-3.5, ChatGPT-4, and Microsoft Bing display varying perspectives on the impact of interest rate increases on commercial banks. ChatGPT-3.5 demonstrates relatively significant variances in identifying several transmission channels through which the effects of interest rate increases manifest, while ChatGPT-4 consistently presents these channels. Furthermore, the ChatGPT-4 responses are more comprehensive and relevant to bank operations. Microsoft Bing's responses seem to be drawn from other websites, resembling a summary of web pages appearing on the first page of search engine results. Despite those differences, each AI response provides valuable insights into the implications of interest rate increases on commercial banks and their operations.