

ARTIFICIAL INTELLIGENCE AND BIG HOLDINGS DATA: OPPORTUNITIES FOR CENTRAL BANKS

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MODELING THE ASSET DEMAND SYSTEM

- ▶ Policy interventions by central banks and financial regulators often change the asset quantities held by, or available to, investors.
- ▶ A realistic asset demand system is key to assess ex post (and predict ex ante) the policy impact on asset prices, the wealth distribution across households and institutions, and financial stability.

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- ▶ A realistic asset demand system is key to assess ex post (and predict ex ante) the policy impact on asset prices, the wealth distribution across households and institutions, and financial stability.
- ▶ What is the asset demand system?
 - ▶ Demand curves of investors for financial assets.
 - ▶ Supply of securities by firms and governments.
 - ▶ Combined with market clearing, we obtain a model of asset prices.

SHORTCOMINGS OF TRADITIONAL MODELS

- ▶ The asset demand system can be micro-founded using assumptions on investors' preferences, constraints, beliefs, ...
- ▶ However, the demand system implied by traditional macro-finance models is misspecified in important ways.

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- ▶ The asset demand system can be micro-founded using assumptions on investors' preferences, constraints, beliefs, ...
 - ▶ However, the demand system implied by traditional macro-finance models is misspecified in important ways.
 - ▶ Specifically, the implied **demand curves are highly elastic**:
 - ▶ E.g., a 10% flow in the aggregate stock market moves equity prices by only 0.5%.
 - ▶ **Implication**: QE, FX management, capital requirements, ESG investing have minimal effects on asset prices.
 - ▶ This prediction is at odds with a growing literature that shows that **demand is much more inelastic** in various asset classes.
 - ▶ E.g., equities, fixed income markets, FX markets.
- ⇒ Limited relevance of traditional models for policy analyses.

DEMAND SYSTEM APPROACH TO ASSET PRICING

- ▶ **Demand system approach to asset pricing:** Estimate the asset demand system directly using rich holdings data, asset prices, and economic fundamentals.
- ▶ This approach has become a practical reality due to
 1. High-quality holdings data.
 2. Improved modeling techniques.
- ▶ Developing plausible micro foundations is an important direction for future research.
 - ▶ Also to mitigate concerns related to the Lucas critique.

OUTLINE

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 - ▶ Designing optimal policies.
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 - ▶ We illustrate the broad applicability of asset demand systems in policy analyses via several examples.
2. Use recent advances in AI to model the asset demand system.
 - ▶ **Main insight:** Just as modeling semantic similarity of words is key in large language models, modeling economic similarity of assets and investors is key in asset demand systems.
 - ▶ **Applications:** Identifying crowded trades, designing stress tests, . . .
 - ▶ Methodology extends to non-financial goods, which can be used to model and understand inflation.

IMPROVED INFORMATION FOR POLICY DECISIONS

DECOMPOSING FLUCTUATIONS IN ASSET PRICES

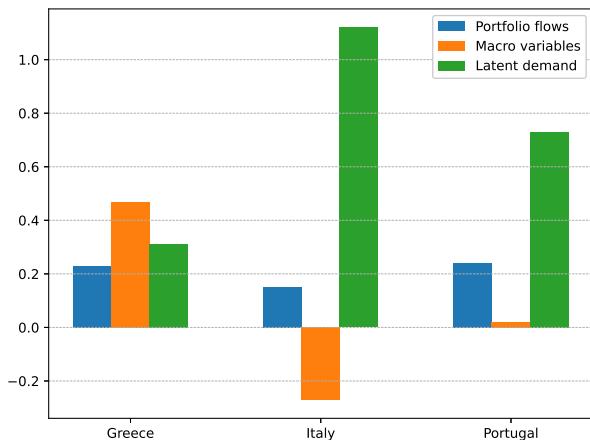
- ▶ The demand system equates the demand of investors to the supply of assets by firms and governments.
- ▶ Hence, for prices to change, one of the elements of the demand system has changed.
- ▶ **Key insight:** We can use the estimated demand system to trace any movement in asset prices to shifts in investors' demand and supply by firms and governments.

UNDERSTANDING FINANCIAL CONTAGION

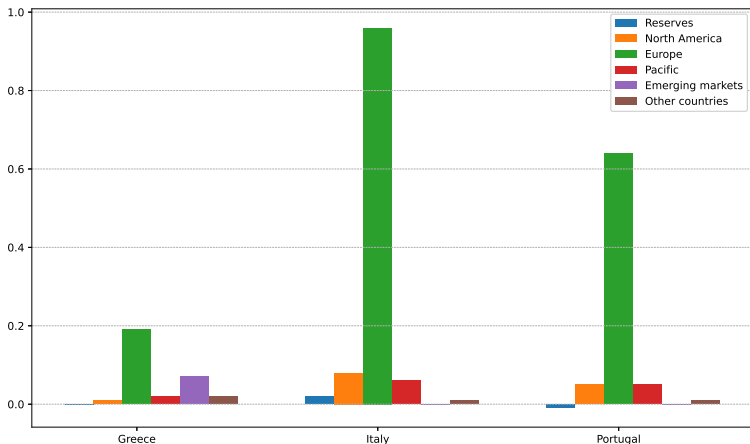
- ▶ Kojien and Yogo (2024): A global asset demand system of
 - ▶ Short- and long-term bond markets
 - ▶ Equity markets
 - ▶ Exchange ratesacross 37 developed and emerging countries.
- ▶ **Application:** What explains the variation in Greek, Italian, and Portuguese yields during the 2009-10 European sovereign debt crisis.

UNDERSTANDING FINANCIAL CONTAGION

- ▶ A variance decomposition of yield spread changes.



UNDERSTANDING FINANCIAL CONTAGION



- ▶ Real-time demand systems provide additional information to policymakers to assess the nature of the shocks that cause key spreads to widen.

UNDERSTANDING KEY ASSET PRICES

- ▶ This methodology has recently been applied to other asset prices of interest to policymakers, such as
 - ▶ Break-even inflation (Bahaj et al., 2023).
 - ▶ Exchange rates (Kojien and Yogo 2024) and specifically the strength of the dollar (Jiang et al., 2024).
 - ▶ Crypto currencies (Benetton and Compiani, 2024).
 - ▶ The systemic risk of large asset managers in equity markets (Kojien and Yogo, 2019).
- ▶ Future research can extend this line of research to asset prices featured in **financial condition indices**.

DESIGNING OPTIMAL POLICIES

IMPACT OF UNCONVENTIONAL MONETARY POLICY

- ▶ Demand systems can be used to model the impact of asset purchase programs on:
 - ▶ Asset prices.
 - ▶ The distribution of risks in financial markets.
- ▶ Kojien et al. (2021) estimate a demand system for sovereign debt in the euro area, and show
 - ▶ Foreign investors are relatively price elastic.
 - ▶ Long-term investors, such as insurance companies and pension funds, instead amplify the purchases of central banks.¹
 - ▶ Estimated multipliers around 0.2-0.4.
- ▶ Demand systems can also be used to explore the impact of multiple central banks implementing QE simultaneously.
 - ▶ E.g., during COVID-19.

¹See also Domanski, Shin, and Sushko (2017).

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- ▶ Gabaix and Koijen (2022) develop a dynamic demand system for the aggregate stock market, with extensions to multiple asset classes.
 - ▶ Equity markets appear to be more inelastic, with multipliers for the aggregate market around 5.
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- ▶ When inflation is low and LT yields are close to the ZLB, optimal QE policy may be to target:
 1. Asset classes that are inelastic.
 2. With a high pass-through to investment / GDP.
 - ▶ Candidates to explore: MBS, corporate bonds, FX, equities.
 - ▶ Estimating substitution patterns and cross-elasticities a key open question.

THE IMPACT OF OTHER KEY POLICIES

- ▶ Currency risk management.
 - ▶ In 2020, central banks' foreign holdings amount to \$1.025 trillion in short-term bond markets and \$4.952 trillion in foreign long-term debt.
 - ▶ The estimated demand system implies that 10% of annual FX movements can be traced back to FX reserves.
 - ▶ This allows for quantification of important channels highlighted in the theoretical literature.²

²Gabaix and Maggiori (2015) and Itskhoki and Mukhin (2021).

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- ▶ Climate stress tests.
 - ▶ Demand systems can also be used to quantify the impact on asset prices and the wealth distribution of climate policies for subsets of investors, such as banks and insurers.³

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USING AI TO MODEL THE ASSET DEMAND SYSTEM

IDENTIFYING SIMILAR ASSETS AND FIRMS

- ▶ To assess policy impact, we often try to find similar firms or assets.
 - ▶ E.g., in terms of growth rates, riskiness, asset substitution in case of QE, product markets to understand inflation, ...
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 - ▶ E.g., industry definitions, accounting data, ...
- ▶ Those characteristics may be quite imperfect.
 - ▶ Standardized accounting data are an incomplete summary.
 - ▶ E.g., “AI intensity,” growth in intangibles, ...
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- ▶ **Main idea:** Use **asset embeddings** to measure firm similarity.

WHAT ARE EMBEDDINGS?

- ▶ **Embeddings:** Represent data (e.g., words) as vectors.
- ▶ Embeddings play a central role in the development of large language models (LLMs).
- ▶ In LLMs, embeddings capture the **similarity between words** and it allows us to do “math with words:

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- ▶ Embedding vectors are **learned** from (lots of) data (**not preselected**).
- ▶ Despite the success of embedding techniques in these fields, their application in finance and economics largely unexplored.

WHICH DATA TO USE TO LEARN EMBEDDINGS?

- ▶ We introduce the concept of **asset embeddings**.
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- ▶ Using holdings data:
 - ▶ Sentences \Rightarrow Investors.
 - ▶ Words \Rightarrow Assets.
 - ▶ **Task:** Guess masked assets.

MASKED ASSET MODELING

► Example: The ARKK ETF in July 2023:

Holdings Data - ARKK

As of 07/07/2023



ARKK

ARK Innovation ETF

	Company	Ticker	CUSIP	Shares	Market Value (\$)	Weight (%)
1	TESLA INC	TSLA	88160R101	3,496,872	\$967,024,982.88	12.43%
2	COINBASE GLOBAL INC -CLASS A	COIN	19260Q107	7,945,138	\$620,515,277.80	7.98%
3	ROKU INC	ROKU	77543R102	8,865,426	\$546,110,241.60	7.02%
4	ZOOM VIDEO COMMUNICATIONS-A	ZM	98980L101	8,258,591	\$534,248,251.79	6.87%
5	UIPATH INC - CLASS A	PATH	90364P105	28,152,366	\$463,106,420.70	5.95%
6	BLOCK INC	SQ	852234103	7,069,493	\$456,759,942.73	5.87%
7	EXACT SCIENCES CORP	EXAS	30063P105	4,031,264	\$368,739,718.08	4.74%
8	UNITY SOFTWARE INC	U	91332U101	8,350,868	\$338,627,697.40	4.35%
9	SHOPIFY INC - CLASS A	SHOP	82509L107	5,430,238	\$335,751,615.54	4.32%
10	DRAFTKINGS INC-CL A	DKNG UW	26142V105	12,035,607	\$303,658,364.61	3.90%

INVESTOR EMBEDDINGS

- ▶ In addition to asset embeddings, we estimate **investor embeddings**.
 - ▶ Learned vector representations of each investor's "taste for characteristics."
- ▶ **Application:** Develop an early warning signal to identify common trading behavior that can destabilize markets:
 1. Crowded trades.
 2. Common exposures to interest rate risk, climate risk, cyber risk, geopolitical risk, . . .

EXTENSIONS AND APPLICATIONS FOR FUTURE WORK

- ▶ Generate stress scenarios.
 - ▶ Simulate scenarios for investors' demand and, by imposing market clearing, asset prices.
- ▶ Other asset classes.
 - ▶ Rich holdings data for fixed income markets (in progress), derivatives markets, and global equities.
 - ▶ **Application:** Improved measurement of the rebalancing channel of QE.

CONCLUSIONS

- ▶ A quantitatively realistic model of the asset demand system is key to assess ex post, and predict ex ante, the policy impact on asset prices, the wealth distribution, and financial stability.
- ▶ Modeling the asset demand system has become a practical reality due to high quality holdings data and modeling advances.
- ▶ Recent advances in AI/ML can be applied to economics and finance via asset and investor embeddings.

CONCLUSIONS

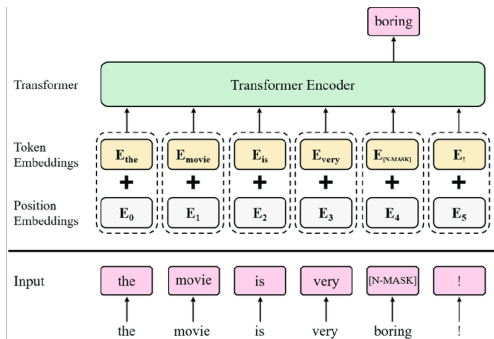
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- ▶ Modeling the asset demand system has become a practical reality due to high quality holdings data and modeling advances.
- ▶ Recent advances in AI/ML can be applied to economics and finance via asset and investor embeddings.
- ▶ **Big plea:** Increase the availability of holdings data for research
 - ▶ Particularly for fixed income, FX, and derivatives.
 - ▶ More high-quality holdings data will improve the models, making them more helpful in policy analyses and making the overall financial system more resilient.

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BERT: MASKED LANGUAGE MODELING

- ▶ A prime example in NLP is BERT⁴ (Bidirectional Encoder Representations from Transformers).
- ▶ The model is trained via masked language modeling.
- ▶ We estimate a version of a transformer model based on the BERT architecture, **AssetBERT**.



⁴Devlin, Chang, Lee, Toutanova (2018).

WHY NOT USE LLMs DIRECTLY?

- ▶ Text asset embeddings do understand firms beyond their names, yet names still matter.
- ▶ Using the language embeddings from OpenAI, we search for the most similar firms (using cosine similarity).
- ▶ OpenAI's embeddings do quite poorly to explain *economic* similarity (rather than word similarity)

	Similar Firms as seen by OpenAI		
Input company	Apple Inc	Citigroup Inc	Walmart Inc
Rank 1	Appian Corp	Citizens Financial Group Inc	Walgreens Boots
Rank 2	Adobe Inc	Goldman Sachs Group Inc	Home Depot Inc
Rank 3	Interdigital Inc	American International Group Inc	Murphy Usa Inc
Rank 4	Microsoft Corp	Comerica Inc	Amazon Com Inc
Rank 5	Gopro Inc	Cigna Corp New	Qurate Retail Inc
Rank 6	Netapp Inc	Capital One Financial Corp	Big Lots Inc
Rank 7	Intel Corp	Caci International Inc	Burlington Stores
Rank 8	Alphabet Inc	Capital City Bank Group	Dollar Tree Inc
Rank 9	Autodesk Inc	C N O Financial Group Inc	Nordstrom Inc
Rank 10	Appfolio Inc	Jpmorgan Chase & Co	Kohls Corp

HOW TO MEASURE SUCCESS?

- ▶ In ML: Benchmark competitions identify the best performing models, and give metrics for success.
 - ▶ E.g. ImageNet to measure improvement in performance in vision tasks.
- ▶ We introduce a series of new benchmarks to assess the quality of embeddings.