RESEARCH STATEMENT: ABSTRACT

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We are in the midst of a historical period where advances in information technologies challenge virtually all aspects of business in traditional financial markets and create new markets altogether. While technology creates opportunities to dramatically reduce allocative frictions, to improve liquidity and informativeness, and to broaden people's access to financial products, it also forces authorities and regulators to rethink the institutions and infrastructure over which markets are built. An integral mission of my research is *understanding how technological advances and institutional developments interplay in asset markets, how they affect their performance, liquidity, and society's welfare.*

Motivated by this goal, my research program contributes to three distinct but related areas, as summarized in the included table. Methodologically, most of my research papers share a two-fold approach. First, developing general equilibrium models of frictional financial exchange where trading protocols, technologies, and institutional rules are explicitly modeled. Second, empirically identifying and quantifying the key frictions and their impact.

Table 1
Summary of my papers by research area

Research Area	**Paper (short title)**	**Technological Developments**	**Institutional Developments**	**Approach**	**Status** (Dec 2019)
The infrastructure and industrial organization of financial markets	Competing on Speed	*Ultra-high-speed networks * Algorithmic trading	* Reg NMS, ATS (US) * Mifid I & II (Europe)	Theory, MQA	Published at ***Econometrica***
	Speed, Fragmentation, and Asset Prices	* Dark pools, smart routing systems		Theory, MQA	Rej.&R at the ***Journal of Finance***
	Central Clearing and Price Volatility	* new CCPs, SEFs	* Dodd-Frank, EMIR * G20 mandate	Causal Inference, Panel data	R&R at the ***Journal of Financial Economics***
Privately informed trading in modern asset markets: strategies, identification, regulation	Chasing Private Information	*Big data * machine learning * FINRA's SONAR	* Dodd-Frank * SEC's CAT * SEC's Whistleblower Reward Program	Textual analysis, Event Studies, Panel data	Published at ***Review of Financial Studies***
	Becker Meets Kyle: Inside Insider Trading		* Newman's ruling	Textual analysis, Causal Inference, Theory	R&R at the ***Journal of Finance***
	Information and Liquidity Trading at Optimal Frequencies	* Transition floor to CLOB trading * Sophisticated retail trading platforms	* Reg NMS, ATS	Theory, MQA, Nonparametric inference	Completed WP
Decentralized payment systems, permissioned/less blockchains	Bitcoin as Decentralized Money	* Decentralized consensus protocols * Bitcoin, Ethereum mining * Ripple, Libra	* Bitcoin network * G20 coordination * SEC/CFTC regulation * Government crypto proposals (e.g., China)	Theory, MQA	R&R at the ***Review of Financial Studies***
	Equilibrium Valuation of Bitcoin and DN Assets	* Lightning		Theory, MQA	Completed WP

Notes MQA: Model-based quantitative assessment (calibration, data fit, simulation experiments). Reg NMS: Reg National Market System. Reg ATS: Reg Alternative Trading Systems. Mifid: Markets in financial instruments directive CAT: Consolidated Audit Trail, CLOB: central limit-order book, EMIR: European Market Infrastructure Regulation.

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1. The Infrastructure and Industrial Organization of Securities and Derivatives Markets

Fragmentation, high-speed trading. The securities exchange industry has changed deeply over the past decade. Entry of new venues has led to fragmentation of trading, particularly in the United States and in Europe. Trading speed has increased a lot in some markets (equities and standardized derivatives in particular), but much trading still relies on human inputs. As a result, we now observe significant heterogeneity in trading across venues and asset classes. These evolutions have triggered heated debates in academic and policy circles. Why do venues invest so heavily in speed? Is there a connection between speed and fragmentation? What are the welfare consequences of these changes? What are the appropriate regulations?

In "Competing on Speed," I (with Philippon) develop a theoretical general equilibrium framework of exchange competition that allows one to study these questions, a market for markets. In the model, trading venues decide whether to enter, subsequently make speed-related investments, and compete for investors who choose where to trade based on available speeds and fees. Once the market structure is in place, investors dynamically trade a security in response to liquidity or preference shocks. We characterize the equilibrium and derive many positive and normative implications. Faster venues charge higher fees and attract speed-sensitive investors. Competition among venues increases investor participation, trading volume, and allocative efficiency, but entry and fragmentation can be excessive, and speeds are generically inefficient. These results are broadly consistent with the experience of European and U.S. markets since the implementation of Mifid I and Reg NMS. We provide regulators with specific guidance for optimal interventions. For example, we find that regulations that protect transaction prices (e.g., SEC trade-through rule) lead to greater venue fragmentation. We show that lower technological costs can dramatically increase trading speed and volume, but the associated welfare gains are small. However, when trading protocols do not favor order front-running, contrary to common wisdom, welfare gains from enforcing a minimum speed can be significant.

Do the aforementioned transformations in secondary asset markets enhance liquidity? What are the consequences for asset prices? I investigate these questions in "Speed, Fragmentation, and Asset Prices" (solo-authored). Competition among venues fragment trading but reduces average trading delays and increases volume. Liquidity improves vis-à-vis a consolidated market, provided thick market externalities are not strong. However, the equilibrium effect on asset prices could, surprisingly, have the opposite sign. Competition between venues, while leaving the relation of tradable assets to market participants unaltered, results in lower market access fees and thus increases the fraction of participating investors. Because of type sorting, as this fraction increases, the market average gains from trade decrease and so does the marginal investor (the one that clears the market) valuation. When the asset supply is not too large, the marginal investor's valuation decreases and fragmentation can thus lead to lower asset prices. The analysis therefore highlights situations where prices can be poor proxies for market liquidity. In general, I show that participation frictions can increases the price volatility of supply shocks. I collect stock market data and use the model to quantify the effect of speed-related and participation frictions on asset prices.

Clearing. A second crucial contemporaneous evolution regards the post-trading infrastructure, i.e., clearing and settlement. In the aftermath of the global financial crisis, a growing consensus has emerged on the fragility of bilateral clearing designs and on the benefits of a central clearing counterparty. Both the Dodd-Frank Act in the United States and the European Market Infrastructure Regulation (EMIR), for example, mandate the central clearing of broad classes of derivatives products. The arguments in favor of the macro benefits of a CCP usually relate to reducing the likelihood of crises and other infrequent tail risks. It is less clear, however, what the micro consequences are for the stability of asset prices at higher frequencies, such as a day or a month, more closely related to the typical investor's decision-making horizon. In "Does Central Clearing Affect Price Stability? Evidence from Nordic Equity Markets" (with Menkveld and Zoican), we seek to provide causal evidence of the effects of the introducing of a CCP on price stability. For that, we adopt as an experimental construct the 2009 clearing reform in three Nordic equity markets. We find that the daily price volatility of the affected equities experiences an economically significant decline of 8.8% relative to pre-reform levels. The decrease in volatility is more pronounced for stocks with a higher margin cost impact, consistent with the predictions of dynamic asset pricing models. We also find that the reform induces a sharp decline of 9.8% in trade volume but no deterioration in market quality as captured by trading costs and information measures. Overall, our results suggest that the adoption of central clearing enhances price stability. Our results also suggest a vital coordination role for policy in implementing clearing reforms, since investors failed to voluntarily clear trades in the CCP when given the option.

What lies ahead? There are further important issues that I would like to investigate next. In Secondary Market Frictions and Primary Financing Costs, (solo-authored), I am currently investigating the connections between market frictions in secondary markets and firm's cost of financing in primary markets. For that, I enlarge the endogenous market structure framework I have developed with an asset issuance stage (the corporate finance stage). This allows evaluating whether, as suggested by many, the current market design in secondary markets is responsible for the lack of IPOs and other forms of equity issuance. I am also interested in further investigating the determinants of the transition of assets from OTC to exchange trading.

2. Privately Informed Trading: Strategies, Identification, Regulation

Asymmetric information is ubiquitous in financial markets, because investors have unequal knowledge of firms' fundamentals. Economists widely accept that the presence of informed agents affects outcomes such as capital formation, efficiency, and welfare. Despite this strong consensus, the empirical testing of such links poses formidable identification challenges, since information sets are virtually never observable. Therefore, most tests rely on asymmetric information proxies under the assumption that these proxies bear a systematic relation with the unobserved presence of informed traders. Common examples of model-based proxies include bid-ask spreads (Glosten Milgrom tradition), trade price impact (Kyle tradition), and order imbalances (Easley O'Hara PIN tradition).

Over the last two decades, the big-data revolution made granular trade-level data sets widely available across asset classes, allowing researchers to produce a large number of papers with such tests. Naturally, the interpretation of results suffers from the joint hypothesis problem.

The over-reliance on simplistic approaches connecting theory and data in this important field motivated me to work in three interconnected lines of research:

(1) Characterizing the behavior of asymmetric information proxies (AIPs) with and without privately informed traders.

(2) Developing theoretical and empirical links between informed traders' actions and legal/regulatory risks.

(3) Developing theoretical and empirical links between the use of private information, trade timing, and liquidity provision in modern markets.

In "Chasing Private Information" (with Kacperczyk), we address (1) by building a unique hand-collected sample of over 450 insider trading investigations by the U.S. SEC and DoJ that document in detail how certain individuals trade on nonpublic and material information. We characterize over 5,000 such unique trades in 615 firms spanning the last two decades. Our first important result is that AIPs largely display abnormal behavior on days with informed trading. Moreover, AIPs exhibit stronger reactions on days with a large proportion of informed trades. Second, AIPs that originate in option markets are valuable. Relative to stock-based AIPs, these AIPs tend to be more sensitive to the presence of informed traders. Third, across stock and option markets, we observe consistent patterns in the direction of market response: volatility and abnormal volume increase, whereas, contrary to conventional wisdom, illiquidity levels decrease. For example, bid-ask spread decreases by about 10% in stock markets and by 20% in option markets when informed traders are present. We provide empirical evidence and simulation results that support three explanations for the puzzling relation between informed trading and illiquidity: the timing of trades, the use of limit orders, and the multivariate learning process of the market maker.

In "Becker Meets Kyle: Inside Insider Trading" (with Kacperczyk), we address (2). Our initial observation is that the literature largely abstracts from *how* private information is produced. In the Grossman–Stiglitz (1980) tradition, a trader pays a fee to become informed, usually regarded as the cost of fundamental research. In real markets, however, private information can also be obtained by an insider in breach of a fiduciary duty, generating exposure to legal risks and converting a regular investor into a criminal. Do such illegal informed traders behave rationally, as in the Kyle model? Do they internalize legal risks, as in Becker (1968)? To provide answers to this question, we first extend a multiperiod Kyle model to incorporate legal risk and random information horizons. We then test the model predictions by combining the records in insider trading investigations with a second hand-built dataset describing the (posterior) legal outcomes for the involved traders. We find that consistent with the model, insiders manage trade size and timing according to market conditions and the value of information. Gender, age, and profession play a lesser role. Then, we design several quasi-experimental tests that provide shocks to either the probability of prosecution and/or conditional penalties. We show that insiders internalize legal risks by moderating aggressiveness, giving support to regulators' deterrence ability. Consistent with Becker's model, following positive

shocks to expected penalties, insiders concentrate on fewer signals of higher value. Thus, we provide evidence that enforcement actions could hamper price informativeness.

I am also interested in better understanding liquidity and information aggregation in modern markets (limit order book venues) where, in contrast to traditional models such as Kyle's and Glosten and Milgrom's, all participants can act as liquidity providers and decide when to trade. For that, in "Information and Liquidity Trading at Optimal Frequencies" (solo authored), I develop a continuous-time model that captures these salient features of modern markets and where, importantly, private information and agents are long-lived. I find that, in equilibrium, both informed and uninformed investors demand and supply liquidity simultaneously, following distinctive time-varying patterns previously found in experiments. As private information is reflected in prices, informed investors rely more heavily on liquidity provision, making limit order quotes relatively more informative near information announcements. Uninformed traders display an opposite pattern, supplying relatively less liquidity as information aggregates. I provide evidence from a proprietary NYSE data provides that supports such implied liquidity provision behavior. My subsequent work with precisely identified information sets described above gives further supports the prediction that informed investors actively provide liquidity to other market participants. The model offers rich structural connections that one can use to evaluate adverse selection risk provided order arrival can be traced.

3. Decentralized Financial Networks: Bitcoin and other Blockchains

In the view of many, the bitcoin network is the most disruptive recent economic innovation. Its rapid growth over the last decade has certainly sparked heated debates. The issue of bitcoin price determination and price volatility is particularly elusive. On the one hand, in investment and entrepreneurial circles, it is often argued that the price reflects fundamental factors such as the growth in the number of network participants and the quality of the underpinning technology. A prominent view in the academic and policy communities, on the other hand, is that bitcoins are just a bubble that will eventually burst and, therefore, bitcoin prices are meaningless. Reaching a consensus on these issues is challenged by the fact that traditional monetary and asset pricing models were not designed around a decentralized network, such as Bitcoin, but a centralized network run by an institution such as a central bank, government, or a corporation. The critical economic innovation in the Nakamoto white paper is that verification and updates to the system ledger (blockchain) are not delegated to a single trusted node but, rather, to a set of miners. The rewards that miners compete for are automatically paid in the same token that is transferred across the network. Therefore, the token serves a simultaneous second role as an incentive device for miners who invest resources that secure the system. In the general equilibrium, the token price and network security must be *jointly* determined. In a sequence of two papers, I study the theoretical implications and positive predictions of this important insight.

"An Equilibrium Valuation of Bitcoin and Decentralized Network Assets" (with Buraschi) formalizes the incentive mechanism as a noncooperative game among miners that seek to obtain block rewards. We model the demand side from the perspective of a utility token, where users of the network can get a service flow and can benefit from the associated network effects. Our equilibrium

asset pricing analysis is, to the best of my knowledge, the first in which prices affect miners incentives and, at the same time, mining activity influence valuations. Among many valuable insights, we find that the embedded miners' incentive mechanism generates excess price volatility for bitcoin.

In "Bitcoin as Decentralized Money: Prices, Mining, and Network Security" (solo authored), I model the dynamics of the supply and demand where bitcoins act, instead, as a means of exchange (intrinsically useless money). I find that, relative to a conventional monetary economy, the price–security loop in the system generates new types of equilibria. In contrast to conventional wisdom arguing that blockchains yield secure dynamic ledgers, I show that the same fundamentals are consistent with low-security equilibria, where the probability of a sabotage attack is high, and high-security ones. In other words, security is a characterizable economic outcome, not an intrinsic property of the 'blockchain technology.' Moreover, I find that, in contrast to conventional monetary economies, changes in nominal supply growth can generate violations to the quantity theory of money. A permanent decrease in nominal growth, for example, lowers inflationary expectations and increase the value of the token. However, a decrease in growth means that bitcoin miners receive smaller nominal rewards. When the initial inflation is low, the associated negative effect on the supply of mining resources could dominate the effect of a weaker debasing, and the price falls. The analysis yields many additional new insights with implications for investors, bitcoin participants, and regulatory institutions.

4. Academic and Broad Impact

My research work is regularly presented at the most prestigious academic conferences in economics and finance, as well as in policy making instituions and industry forums. I include a selected list by research area in the table below.

Table 2
Selected Presentations and Distinctions

Research Area	Refereed Academic Conferences	Policy institutions	Industry	Distinctions
The infrastructure and industrial organization of financial markets	* Western Finance Association * American Economic Association * American Financial Association * Finance Theory Group * SFS Cavalcade * NYU Stern Microstructure (prev. NBER microstructure) * Econometric Society * Cowles Foundation	* Bank of England * Federal Reserve Bank of New York * Federal Reserve Bank of Philadelphia * Federal Reserve Bank of Chicago	* Chicago Quantitative Analysis/Society of Quantitative Analysis * Euronext Hedge Fund Conf. * Brevan Howard conf. HFT	* Grant from the Smith Richardson Foundation * CQA/SQA Annual academic speaker * Publication request for special issue on Fragmentation, Rev. of Econ. Dynamics
Privately informed trading in modern asset markets: strategies, identification, regulation	* American Financial Association * Western Finance Association * European Financial Association * NBER Asset Pricing * NBER Long-Tern Asset Mgmt * NBER Economics of Crime * CEPR Conf. * FIRS Conf. * SFS Cavalcade	* Federal Reserve Board of Gov. * Financial Conduct Authority	* AQR Hedge Fund * SAC Capital Hedge Fund * Buyside Liquidity Conf. * The World Federation of Exchanges	* QSRI award to organize "Frictions in Finance: Theory and Evidence"
Decentralized payment systems, permissioned/less blockchains	* NBER Asset Pricing * American Economic Association * American Financial Association * European Financial Association * Finance Theory Group * FIRS Conf. * Finance Theory Group * Toronto Fintech Conference	* Bank of Canada * Central Bank Research Association	* Bloomberg Annual Crypto Summit * Blockchain Economic Forum	* Best Crypto Economics Paper Award, Toronto Fintech Conference * Featured by Bloomberg as the first bitcoin valuation framework