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Time-varying arbitrage and dynamic price discovery

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ABSTRACT

We introduce time-varying measures of price discovery based on underlying profit maximizing behavior by combining the heterogeneous agent modelling literature with the market microstructure literature. We set up a heterogeneous agent model with arbitrageurs and trend chasers (chartists), and allow agents to switch between the strategies conditional on recent forecasting performance. Estimation of the model on Canadian-US cross-listed stocks on high-frequency data shows that there is significant heterogeneity and switching, causing ample variation in the information processing capacity of markets.

1. Introduction

This paper develops an empirical heterogeneous agent model to explain time variation in price discovery for cross-listed assets. Building on a model that allows for both arbitrageurs and trend chasers, we demonstrate that price discovery becomes a function of which type of trader is active in the market. We empirically apply the model to a sample of Canadian firms that are cross-listed in the US. Using intraday data sampled at a one-second frequency, we document significant switching between arbitrage and trend chasing strategies. This induces time variation in price discovery and can explain e.g. an intraday pattern in the contribution to price discovery for each market.

Despite its mathematical elegance and convenience, evidence against the notion of a rational representative agent has been mounting; see e.g. Hong and Stein (2007). One response to this evidence against the representative agent model comes from the literature on heterogeneous agent models (HAMs). HAMs are endowment-based asset pricing models in which agents distribute wealth between a risky asset and a risk-free asset in order to maximize (mean-variance) utility. The innovation is that HAMs allow agents to have heterogeneous expectations about the future prospects of an asset; see Hommes (2006) for an overview. Typically, the models contain two types of traders: fundamentalists and chartists, who expect mean reversion and trend continuation, respectively. Furthermore, agents are allowed to switch between these two groups conditional on their relative performance. The literature on heterogenous agent models has demonstrated that allowing for agents to have heterogenous beliefs and allowing them to switch between these beliefs can generate several stylized facts of financial markets, such as excess volatility, volatility clustering, and heavy tails (see e.g. De Grauwe and Grimaldi, 2006).

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Empirically, HAMs have been applied to a wide range of assets, from explaining stock price behavior (Boswijk et al., 2007; Chiarella et al., 2014) to exchange rate dynamics (De Jong et al., 2010) to option pricing (Frijns et al., 2010); see Lux and Zwinkels (2018) and Chen et al. (2012) for an overview of the empirical literature. Although the models are non-linear in nature and therefore slightly more challenging to estimate, heterogeneity and time variation is introduced in a highly parsimonious way by using only one additional parameter. The studies consistently find that introducing heterogeneity and switching in otherwise standard asset pricing models increases the fit of the model significantly. In addition, the approach has been shown to outperform benchmark models in out-of-sample forecasting exercises (see e.g. Kouwenberg and Zwinkels, 2014).

In this paper, we apply a HAM in a novel setting, namely, to study the price discovery process for cross-listed assets. The novelty in this context is threefold. First, we develop a HAM that allows for agents to switch between arbitrage and trend chasing strategies in two (risky) assets markets,[1] and document that this model performs significantly better than a model that does not allow for heterogeneity. Second, to the best of our knowledge, this is the first paper that brings HAMs into the high frequency domain. Existing empirical studies using HAMs consistently use lower frequency data. However, to study price discovery, high-frequency data is crucial as informational advantages cannot be observed with low-frequency data. We document that high-frequency data in combination with a HAM can be used to explain time-variation in price discovery. Third, we link the empirical heterogeneous agent literature to the microstructure literature and demonstrate that price discovery measures are affected by the proportion of arbitrageurs/trend chasers present in the market. Hence, time variation in the proportion of arbitrageurs results in time variation in price discovery.[2]

We also contribute to the literature on price discovery (e.g. Garbade and Silber, 1979; Hasbrouck, 1995). The market microstructure literature has long been interested in the process of how information is impounded into prices. This question becomes particularly relevant when an asset is listed on multiple exchanges. In such a case, the question becomes which market is more efficient in incorporating information into prices and why. Thus far, the literature on price discovery has predominantly focused on the contribution of markets to price discovery and cross-sectional determinants of price discovery. We contribute to this line of literature by introducing an endogenous and time-varying measure of price discovery that is conditional on the type of trader active in the market at each point in time. Therefore, by combining a HAM with high-frequency data we not only introduce time variation in price discovery, but also provide an economic explanation for this time variation.[3]

We show that our empirical heterogeneous agent model reduces to a vector error correction model with time-varying coefficients conditional on the relative importance of arbitrage and trend chasing. Our empirical findings show that the error correction model that allows for switching between arbitrageurs and trend chasers significantly improves on a static error correction model. This demonstrates that there is indeed time variation in the weights on arbitrage and trend chasing strategies, and that the dynamics of these weights are driven by the past forecasting performance of the respective investment strategies. This time variation in weights leads to time variation in the speed of adjustment coefficients, which in turn leads to time variation in price discovery. Through simulation analysis, we demonstrate that this variation can be substantial. Empirically, we observe that the introduction of multiple strategies, and allowing for switching between these, results in considerable time variation in price discovery , and can explain e.g. an intraday pattern in price discovery.

The remainder of this paper is structured as follows. Section 2 provides an overview of the relevant literature on heterogeneous agent models and the literature on price discovery. In Section 3, we develop a model that allows us to explain time variation in price discovery. Section 4 discusses the data we employ in this study. In Section 5, we present the results of our analysis. Finally, Section 6 concludes.

2. Literature

Our paper builds on the heterogeneous agent modeling literature due to Brock and Hommes (1997, 1998). These models assume that agents have boundedly rational and heterogeneous expectations regarding the future value of an asset. Agents are typically assumed to be of the fundamentalist type, having expectations of mean reversion, or of the chartist type, relying on extrapolation of recently observed price patterns.[4] What makes these models unique is that investors can switch between the fundamentalist and chartists strategies and do so based on the relative past performance of these strategies. This switching between strategies is controlled by the so-called intensity of choice parameter, which is key in generating the nonlinear dynamics. Through numerical analysis, these studies not only demonstrate that these models can generate nonlinear dynamics and stylized facts, such as volatility clustering, excess volatility, and heavy tails in single markets (De Grauwe and Grimaldi, 2006), but also explain stylized facts observed between markets, such as comovements between stock prices, cross-correlation of volatility and other commonalities (Schmitt and Westerhoff, 2014).

[1] This implies several deviations from the benchmark setting: (1) multiple asset markets rather than one single risky asset; (2) alternative trader types to the archetypical fundamentalists and chartists; and (3) no need to define a fundamental value due to the arbitrage relation between markets.

[2] There are theoretical HAM studies that look into the effect of the market microstructure on price formation and stability; see e.g. Chiarella et al. (2009).

[3] This is in contrast to purely statistical approaches to introduce time variation based on, for example, state-space, generalized autoregressive score, or regime switching models.

[4] This choice is motivated by experimentally observed behavior; see e.g. Bloomfield and Hales (2002).

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