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Modelling price pressure in financial markets

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ABSTRACT

We present experimental evidence that, unlike traditional assumptions in economic theory, security prices do not respond to pressure from their own excess demand. Instead, prices respond to excess demand of all securities, despite the absence of a direct link between markets. We propose a model of price pressure that explains these findings. In our model, agents set order prices that reflect the marginal valuation of desired future holdings, called "aspiration levels."

In the short run, as agents encounter difficulties executing their orders, they scale back their aspiration levels. Marginal valuations, order prices, and hence, transaction prices change correspondingly. The resulting price adjustment process coincides with the Global Newton Method. The assumptions of the model as well as its empirical implications are fully borne out by the data. Our model thus provides an economic foundation for why markets appear to search for equilibrium according to Newton's procedure.

1. Introduction

Economists have generally focused on the equilibrium implications of their models, leaving little time to consider how markets attain equilibrium. This focus is motivated by the claim that prices "move in accord with the excess demand (demand minus supply) in each market" (Negishi, 1962, 638). If excess demand is positive (there is more demand than supply), prices tend to increase. Conversely, if excess demand is negative (supply outstrips demand), then prices tend to decrease. As a result, price adjustment only stops at the point where excess demand equals zero, the equilibrium.

The above process is what Walras first developed in his *Élements d'Économie Politique Pure* (1874) and what has subsequently remained one of the most studied price-adjustment processes.[2] As Gode and Sunder (1993, 120) proclaim, "Standard economic theory is built on two specific assumptions: utility-maximizing behavior and the institution of Walrasian tatonnement."

The Walrasian tatonnement theory builds on the intuitive premise that prices react to the demand in their own market only. Since the demand for a given asset already incorporates the substitution and complementarity effects between this and the other traded assets, there is no compelling reason why prices should react to anything but own excess demand. Unfortunately, if it is true that prices adjust only in the direction of own excess demand, the adjustment process may not converge. It is easy to construct counterexamples (see, e.g., Scarf, 1960). The counterexamples exploit the fact that

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2 For a comprehensive treatment of the issues of disequilibrium and equilibration of economic systems the reader is referred to Herings (1996) as well as Arrow and Hahn (1971).

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no general shape restrictions exist for excess demand as a function of prices (this fundamental result is known as the Debreu–Mantel–Sonnenschein Theorem). Thus, for price adjustment to be generically converging and, hence, for equilibrium to be the natural state towards which markets tend, it better be that prices adjust to *something else besides own excess demand.*

Evidence is presented here that markets do adjust differently. We study the outcomes in financial markets experiments where up to 70 (human) subjects traded four (three risky and one risk-free) securities for real money. Prices of none of the risky securities correlate significantly to their own excess demand, contrary to the *tatonnement* theory. The lack of correlation is caused by the presence of excess demand in other securities. Evidently, prices in one market react to excess demand of *all* markets, not only their own market, even if there is no direct link between markets.[3,4]

Such cross-security effects can arise within the well known Global Newton Method for the numerical computation of general equilibrium (see Arrow and Hahn, 1971, and Smale, 1976a). However, unlike the Walrasian tatonnement that is constructed to mimic the "invisible hand," the Newton procedure lacks any economic intuition, and there is no reason to believe that the outcome of real trading will coincide with such an adjustment process.[5]

The main goal of this paper is to develop and further test a behavioral theory that explains the cross-security effects and as such provides an economic foundation for the price adjustment based on Newton's method. We model excess demand assuming that individuals want to trade off expected return against variance. That is, excess demands are computed as in the *capital asset pricing model* (CAPM). This choice is justified because the CAPM explains eventual pricing in the experiments as well as end-of-period portfolio holdings.[6]

Our model postulates that, in the short run, agents attempt to trade towards *aspiration levels*. Although not necessary, we take the aspiration levels to be the optimal positions at last transaction prices: aspiration levels equal current positions plus excess demands. These are also the aspiration levels in the classical Walrasian tatonnement, but the subsequent price adjustment in the Walrasian model is mechanical and fictitious: prices are assumed to change in proportion to excess demand. In contrast, our model spells out how agents would react when their orders (which are based on their aspiration levels) fail to be executed. Specifically, we conjecture that agents scale back their aspiration levels towards their current holdings. Marginal valuations are updated correspondingly (i.e., prices at which agents are willing to trade are revised).[7] Mean order prices and as a result prices at which subsequent transactions are likely to occur, change.

Mathematically, the set of difference equations resulting from the aggregation of the individual reactions to unfilled excess demands coincides with the set of equations of the Newton's numerical procedure. Thus, our theory provides an explanation for why it appears that real markets use the Newton procedure in their search for equilibrium.[8] More specifically, price pressure in our model is driven by local changes in marginal valuations, which in turn are dictated by the Hessian of agents' utility functions. In the case of mean-variance preferences, the Hessian is proportional to the covariance matrix of the final payoffs. When covariances are nonzero, not only does our model therefore predict the presence of cross-security effects, but also that these cross-security effects are related to the sign and even the magnitude of these covariances.

In our subsequent empirical analysis we first test whether the main assumptions of our model about individual behavior hold in the data.[9] We find significantly positive correlations (equal to 40 percent on average) between individual cancelation rates in different markets, thus obtaining support for the assumption that agents proportionally scale back their unfilled orders. The model further assumes that the more risk averse individuals scale back less than the agents with higher risk tolerance. We find that there is indeed (albeit weak) positive correlation between individual risk tolerance and the rate of order cancelations in the experimental markets.

The empirical predictions of the model are fully borne out by the experimental data: there is a systematic relationship between, on the one hand, the cross-security effects and, on the other hand, the covariances of the final payoffs of the securities. In particular, if two securities have negatively correlated payoffs, then their prices tend to be negatively correlated with each other's excess demands (*vice versa* if the correlation is positive); moreover, the magnitude of the cross-security effects is related to that of the payoff covariances.

We recognize that the scope of the model is limited. It deals only with the mechanics of the direction in which prices change given unattainable aspiration levels. That is, ours is not a model of equilibration, but it could be embedded in a model of equilibration. One possibility is the following. As aspiration levels are scaled back and marginal valuations change, the

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[3] Order execution in one market is not contingent on events in other markets.

[4] The cross-security effects were first discovered in experimental markets with three securities (two risky, one risk-free); see Asparouhova et al. (2003). This paper demonstrates that the effects are replicable. In addition, the four-security environment reveals rich patterns in the signs and magnitudes of the covariances between a security's price changes and other securities' excess demands, which Asparouhova et al. could not detect because they investigated experiments with only two risky securities.

[5] Arrow and Hahn (1971, 304) point out that the price process derived from Newton's method does not mimic the invisible hand since "the price of a good may be raised even though it is in excess supply."

[6] CAPM explains end-of-period portfolio holdings *modulo* a random error term. The moderate level of risk in the experiments may explain subjects' tendency to ignore higher-order moments (e.g., skewness). See Bossaerts and Plott (2004), Bossaerts et al. (2007).

[7] Say an agent submits a limit buy order of q units in one of the markets at the last transaction price. If there is overall excess demand and the order is not executed, the agent scales the quantity back to $(q - \Delta q)$ and submits a new limit order. The new price is the marginal valuation of the asset at the new order quantity.

[8] The observation that markets appear to use Newton's procedure when discovering equilibrium was made in Asparouhova et al. (2003, 14). However, the authors "leave it to future work to explore explanations for the relationship between price discovery and Newton's procedure."

[9] We thank an anonymous referee for suggesting the tests for the model's assumptions.