Learning to forecast: Genetic algorithms and experiments

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Samenvatting (Summary in Dutch)

Prijsverwachtingen blijven een controversiële kwestie in de economische literatuur. Recente marktontwikkelingen, waaronder de financiële crisis van 2007, trekken de traditionele denkbeelden van perfecte rationaliteit en marktefficiëntie in twijfel. Zogeheten Learning-to-Forecast-experimenten (LtF) tonen aan dat proefpersonen, wanneer ze geconfronteerd worden met feedback tussen verwachtingen en gerealiseerde prijzen, heterogeen blijven en simpele gedragsregels volgen. De precieze keuze voor een gedragsregel hangt af van het soort feedback. Het belangrijkste onderscheid dat gemaakt wordt is tussen markten met een negatieve dan wel een positieve feedbackstructuur. Bij negatieve feedback, zoals in een economie met producenten van een bederfelijk goed, is de gerealiseerde prijs negatief gecorreleerd met de verwachtingen. Dit duwt proefpersonen in de richting van adaptief gedrag, waardoor ze coördineren op de rationele, fundamentele oplossing.

Daarentegen worden financiële markten juist gekenmerkt door een *selffulfilling* positieve feedbackstructuur. Zo zullen optimistische agenten de vraag naar een financieel product doen toenemen, waardoor de prijs van dit product ook daadwerkelijk stijgt. LtF-experimenten tonen aan dat proefpersonen in een omgeving met dergelijke positieve feedback leren om prijstrends te extrapoleren, hetgeen resulteert in grillige en niet-convergerende prijsoscillaties. Het doel van dit proefschrift is om het Learning-to-Forecast-gedrag, d.w.z. het leren om te voorspellen, nader te bestuderen. We richten ons op een leermodel met Genetische Algoritmen, het fitten hiervan op data uit LtF-experimenten, en de toepassing van het model op uiteenlopende experimentele markten. We voeren ook een experiment uit om de robuustheid van de LtF-opzet te onderzoeken. Het proefschrift bestaat uit drie gerelateerde, maar onafhankelijke hoofdstukken.

In Hoofdstuk 2 ontwikkelen we een model waarin agenten Genetische Algoritmen gebruiken die een algemene voorspellingsheuristiek optimaliseren om prijsverwachtingen te vormen (Hommes en Lux, 2013). We passen het model toe op vier experimentele omgevingen:

- lineaire positieve en negatieve feedback (Heemeijer et al., 2009);

- lineaire positieve en negatieve feedback met grote, onverwachte schokken op de fundamentele waarde (Bao et al., 2012);

- een niet-lineaire varkenscycluseconomie (Hommes et al., 2007; van de Velden, 2001);

- een niet-lineaire aandelenmarkt waarin agenten twee perioden vooruit voorspellen (Hommes et al., 2005).

Ons model presteert beter dan Rationele Verwachtingen, een aantal andere homogene verwachtingsregels (naïeve, adaptieve, trend-extrapolerende en 'contrarian'-verwachtingen) en een eenvoudig Heuristiek Switchingmodel met heterogene verwachtingen. In het bijzonder heeft het model een zeer hoog voorspellend vermogen wat betreft out-of-sample kortetermijnvoorspellingen. Daarnaast is het het enige model dat in staat is *individueel* gedrag te verklaren en de experimentele dynamica op de *lange termijn* (vijftig perioden vooruit) te voorspellen. Het biedt ook een rechtvaardiging voor het gebruik van het Heuristisch Switchingmodel als een gestileerde beschrijving van experimentele dynamica. Dit is een belangrijke bijdrage aan de literatuur, aangezien beleidsmakers de laatste jaren op zoek zijn naar economische modellen met robuuste microfunderingen van gedrag.

In Hoofdstuk 3 gebruiken we het Learning-to-Forecast-model met Genetische Algoritmen voor het bestuderen van informatienetwerken in financiële markten. Het doel hiervan is om het effect van informatiestromen op marktstabiliteit te evalueren. We concentreren ons op een niet-lineair model voor aandelen waarin agenten twee perioden vooruit voorspellen. De agenten leren of ze de geobserveerde prijstrend moeten extrapoleren, en ook of ze moeten vertrouwen op de gemiddelde gemoedstoestand van de vrienden die ze observeren in het netwerk. We laten zien dat zonder een netwerk agenten kunnen coördineren op ofwel de fundamentele waarde, ofwel trendvolgend gedrag. Dit laatste doet de markt overschakelen van de fundamentele oplossing naar grillige prijsoscillaties. Het toevoegen van een netwerk, ongeacht de architectuur of grootte, destabiliseert de markt, die vrijwel nooit in de fundamentele oplossing blijft. Dit volgt uit twee gerelateerde observaties. Ten eerste leren de agenten te coördineren op sterkere trendvolgende regels. Ten tweede leren de agenten 'contrarian' gedrag: ze zijn optimistisch als ze observeren dat hun vrienden in het verleden verkochten en *vice versa*. De reden voor het contrarian gedrag is dat de agenten proberen hun vrienden te slim af te zijn. Een voorbeeld hiervan is dat op het moment dat de zeepbel in elkaar begint te klappen een agent zich bewust wordt van een negatieve trend, maar ook van het feit dat haar vrienden tot aan het hoogtepunt van de zeepbel het aandeel hebben

gekocht. Ze heeft daarom een prikkel om aandelen te verkopen, m.a.w. te handelen in tegenstelde richting van haar vrienden.

Het model voorspelt dat de agenten – ondanks hun contrarian houding – leren een gelijksoortig gedrag aan te nemen en daardoor goed gecoördineerd blijven. Dit is een belangrijk inzicht voor de tegenstrijdige opvattingen die in de literatuur bestaan over kuddegedrag. Experimenten tonen aan dat personen contrarian strategieën gebruiken (d.w.z. anti-kuddegedrag), hetgeen inderdaad overeenkomt met het gedrag in onze simulaties. Aan de andere kant leidt een gelijksoortig leerproces van de *contrarian* houding ertoe dat agenten een *gelijksoortig gedrag* aannemen. Dit kan ten onrechte geïnterpreteerd worden als kuddegedrag.

Hoofdstuk 4 doet verslag van een experiment gebaseerd op een eenvoudig lineaire aandelenmarkt, waarin proefpersonen gevraagd werd prijzen te voorspellen, het aandeel te verhandelen, of beide. Het belang van dit experiment is dat het een verbinding legt tussen Learning-to-Forecast- en Learning-to-Optimize-experimenten. Het kan daarom dienstdoen als een nuttig referentiepunt voor toekomstige theoretische en experimentele onderzoeken naar leren in aandelenmarkten.

We vinden dat in elke variant van het experiment proefpersonen coördineren op niet-fundamentele uitkomsten: ofwel stabiele prijzen ver van de fundamentele waarde, ofwel aanhoudende prijsoscillaties. De Learning-to-Optimize- en gemengde variant van het experiment zijn instabieler; de grootste zeepbel (op het hoogtepunt ongeveer 3.5 keer de fundamentele waarde) vond plaats bij een van de groepen in de gemengde variant. Deze resultaten laten zien dat het leren om te optimaliseren voor de proefpersonen nog moeilijker is dan het leren om te voorspellen. Bovendien blijken de resultaten van de LtF-experimenten robuust te zijn, in de zin dat prijsoscillaties niet slechts een artefact zijn van de versie van het experiment waarin proefpersonen voorspellen. We vinden ook bevestiging voor statistisch significante heterogeniteit in de gedragsregels van de proefpersonen.

Het meest verrassende resultaat komt uit de gemengde variant van het experiment waarin zowel de transacties als de corresponderende prijsvoorspelling geobserveerd worden. Hierdoor kunnen we expliciet toetsen voor hun consistentie. We vinden dat slechts een kwart van de proefpersonen optimaal handelt conditioneel op hun geïmpliceerde verwachtingen van het rendement van het aandeel. Dit is een empirisch bewijs tegen het idee dat economische agenten perfecte optimaliseerders zijn — een populair idee, zelfs onder voorstanders van begrensd rationele prijsverwachtingen. Nader onderzoek zal zich richten op theoretische modellen van het leren om te optimaliseren, en de verbinding hiervan met het leren om te voorspellen.

The Tinbergen Institute is the Institute for Economic Research, which was founded in 1987 by the Faculties of Economics and Econometrics of the Erasmus University Rotterdam, University of Amsterdam and VU University Amsterdam. The Institute is named after the late Professor Jan Tinbergen, Dutch Nobel Prize laureate in economics in 1969. The Tinbergen Institute is located in Amsterdam and Rotterdam. The following books recently appeared in the Tinbergen Institute Research Series:

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