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# Heterogeneous expectations in the gold market: Specification and estimation



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## ABSTRACT

The increase in the price of gold between 2002 and 2011 appears to be a candidate for a potential asset price 'bubble', suggesting that chartists (feedback traders) were highly active in the gold market during this period. Hence, this paper develops and tests empirically several models incorporating heterogeneous expectations of agents, specifically fundamentalists and chartists, for the gold market. The empirical results show that both agent types are important in explaining historical gold prices but that the 10-year bull run of gold in the early 2000s is consistent with the presence of agents extrapolating long-term trends. Technically this paper is a further step toward providing an empirical foundation for certain assumptions used in the heterogeneous agents literature. For example, the empirical results presented in this paper compare the economical and statistical significance of numerous switching variable specifications that are generally only introduced ad hoc.

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## 1. Introduction

Gold prices have exhibited a strong positive trend between 2002 and 2011 with gold rising from around 300 US dollar in 2002 to values well above 1900 US dollar per troy ounce in 2011. Comparing this to the relatively stable period for the 20 years previous there has been much discussion about the cause for this upward trajectory. Many commentators have identified the recent trend as a bubble<sup>1</sup> (similar to the sharp rise and subsequent correction in gold prices in the late 1970s and early 1980s) whilst many others have suggested that there has been a structural change in the prices and volumes in the gold market—and commodity markets in general—in recent years.<sup>2,3</sup>

This paper attempts to shed some light onto these issues through the use (and estimation) of a heterogeneous agents model (henceforth HAM) for the gold market in which fundamentalists are convinced that the price will return to its

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<sup>1</sup> See, for example, "Gold price bubble a 'high probability' says Deutsche Bank", *Financial Times*, January 13, 2011 (<http://www.ft.com/cms/s/0/2e36ccf4-1f33-11e0-8c1c-00144feab49a.html>), or 'Cash out of gold and send kids to college', *Financial Times*, August 7, 2012 (<http://www.ft.com/intl/cms/s/0/312bf416-d1a7-11e1-bb82-00144feabdc0.html#axzz2K5AdpTV4>).

<sup>2</sup> See, for example, 'Gilt-edged argument', *The Economist*, April 28, 2011 (<http://www.economist.com/node/18620836>).

<sup>3</sup> The period from 2004 until recently is sometimes referred to as a period of 'financialization' of commodities (e.g. see [Tang and Xiong, 2013](#)) since there has been a dramatic increase in the presence of institutional investors in commodity markets who use these markets for the purpose of asset management. Furthermore, the introduction of exchange-traded funds around 2002 has augmented this trend by providing both institutional and retail investors with additional opportunities to obtain exposure to commodities in general and gold in particular.

'fundamental' value and chartists, on the other hand, aim to identify price signals from past price trends. The use of a HAM in the gold market can be justified by the observation that the historical gold price has exhibited a strong and *relatively long* positive trend which can be explained with chartist traders buying an asset whose price increased in the past thereby enforcing or prolonging the trend. This behaviour is in contrast to a fundamentalist, who would trade toward the fundamental value. A long and positive price trend can thus only be explained by a continuously rising fundamental value or the presence of chartists. We think that the latter, i.e. the presence of chartists or chartist-behaviour, is perhaps a more plausible assumption than a continuously rising fundamental price.

Furthermore, if there is significant evidence for the presence of chartist traders it is likely that their trades have changed the properties often associated with gold, in particular the store of value and the safe haven attributes.<sup>4</sup> Hence, the chartist–fundamentalist approach offers a new and promising alternative behavioural perspective on historical gold price dynamics. To the best of our knowledge, this is the first such empirical work focusing on the gold market.

Specifically, we develop a parsimonious HAM for the gold market in which agents are assumed to adapt their heterogeneous beliefs in response to the arrival of new information, and therefore switch between different trading strategies.<sup>5</sup> Despite their theoretically appealing features, however, there are many different alternative model specifications available in the HAMs literature; each producing potentially different results. With this in mind, we also consider different variations of our model with different switching specifications.<sup>6</sup>

Our empirical findings (based on 43 years of monthly data) are in line with predictions from heterogeneous agent theory. In particular, we find strong evidence that the bubble-like price path of gold observed during the 1970/80s can be characterized well by short-term trend-followers and long-term stabilizers (fundamentalists). In more recent times however, the gold price appears more consistent with *long-term* trend-following and short-term *contrarian* chartist behaviour; with little evidence of 'classical' fundamentalist activity. This indicates that the lack of stabilizing agents in the gold market between 2002 and 2011 was a contributing factor to the steadily increasing gold price. Furthermore, an alternative specification with asymmetric demands reveals that agents have generally only followed positive price trends. We explain this result with the significant costs of short-selling gold.

In regards to the switching within our model, results consistently show that the added flexibility of agents to adapt their beliefs increases model fit and the significance of agents' impact on price dynamics. There is also evidence of consistent *qualitative* behaviour of agents (i.e. parameter sign) across switching variables, but considerable variation in the *quantitative* effects (i.e. model fit and estimated parameter magnitudes) across switching variables; demonstrating the importance of considering such alternative model specifications. To this end, we find that simple measures of gold price volatility and (risk-adjusted) measures of the deviation of the gold price from the fundamental value of gold perform equally as well as more well-known measures such as the past profit measure introduced by Brock and Hommes (1997, 1998). It is our hope that a comparison of the different switching specifications within this market will provide valuable insight for further theoretical and empirical developments of HAMs for other markets.

### 1.1. Related literature

Models of asset price dynamics based on the interaction of heterogeneous agents have become increasingly popular in recent years.<sup>7</sup> These models are appealing since they allow for more flexibility in the modelling of investors behaviour than classical rational expectations would allow. Furthermore, even some of the simpler models in this class appear to explain well many of the stylized empirical facts of observed asset price dynamics. Such models essentially posit that asset prices are driven to some degree by an endogenous nonlinear law of motion.

In the majority of the existing theoretical literature, it is found that chartists tend to destabilize markets (increase volatility), whereas fundamentalists act as a stabilizing force on price dynamics. The dynamic interaction between these two agent types leads to periods of both mean-reverting and explosive behaviour.<sup>8</sup> To account for the additional role of gold as a real (as opposed to financial) asset, we also explicitly model the effect of real supply and demand on the gold price dynamics, such effects can be seen to provide an additional stabilizing force on the gold price.

When it comes to the empirical estimation of heterogeneous agent models, there is a developing literature but there appears still much work to be done. This sentiment is echoed in Chiarella et al. (2009) who state in their conclusions that 'much more needs to be done on the calibration and estimation' of the models surveyed in their paper. The relatively late development of empirical studies in this area is no doubt due to the highly nonlinear nature of such models and the

<sup>4</sup> Baur and Glover (2012) analyse the effect of increased (speculative) investment on the safe haven property of gold. The safe haven property of gold is closely related to a 'flight-to-quality' from stocks to gold.

<sup>5</sup> This idea, influenced by the discrete choice modelling literature (see Manski and McFadden, 1981; Anderson et al., 1993), was developed by Brock and Hommes (1997, 1998) who coined it the 'adaptive belief system'.

<sup>6</sup> We do not consider exogenous variables in this paper, only endogenous ones, i.e. lagged prices, simple or squared log-price differences etc. While the use of exogenous variables offers a large set of modelling opportunities the choice of such variables is not straightforward and we therefore restrict ourselves to a 'classical' time-series analysis.

<sup>7</sup> For a detailed survey of the history and state-of-the-art of heterogeneous agents models see Hommes (2006), Hommes and Wagener (2009), Chiarella et al. (2009), or more recently Chen et al. (2012).

<sup>8</sup> It is worth noting at this stage that the interpretation of chartists and fundamentalists need not be distinct traders but different motives of a single individual for changing their holdings.

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