Technical Analysis, Price Trends, and Bubbles

For presentation at Sixth International Conference on
Computing in Economics and Finance, July 2000

David Goldbaum
Department of Economics
Rutgers University
360 Dr. Martin Luther King Jr. Blvd.
Newark, NJ 07102
Phone: (973) 353-5164
Fax: (973) 353-5819
E-mail: goldbaum@andromeda.rutgers.edu.

Abstract

Traders endogenously select an information source to maximized expected profits. Those traders selecting to use fundamental information receive a noisy indicator of next period's dividend and construct a portfolio to maximize expected utility. The other option is to employ a technical trading rule. Due to the noise in the fundamental signal, optimal behavior by the fundamental traders creates patterns in the price which can profitably be exploited by the technical trading rule. The technical trading rule performs best when the price is dominated by the fundamental traders. Endogenous swings in the popularity of the technical trading rule can create price bubbles which amplify the movement of the underlying intrinsic value.

Keywords: Asset Markets, Bounded Rationality, Technical Analysis, Chaotic Systems
JEL Classifications: G14, G11, C15

Technical Analysis, Price Trends, and Bubbles

Academics in economics and finance typically discount evidence of the usefulness of technical trading rules. The Efficient Markets Hypothesis provides the theoretical foundation with which technical trading rules are rejected. Market efficiency implies that market prices reflect the most recently available information. Thus, in an environment of efficient markets, past price patterns cannot be used to forecast future returns. Technical trading rules, which provide the user with a signal of when to buy or sell an asset based on such price patterns, should not be useful for generating excess returns.

Despite academic admonitions, use of technical trading rules is widespread. The finance section of any good bookstore offers a large selection of books purporting successful strategies based on trading rules. The books contain examples, advice, and sometimes explanations of how and why each trading rule works. Weekend and cable television programs feature chartists who make recommendations based on their readings of charts and technical trading rules. Many firms employ chartists in house or subscribe to chartist services through newsletters. Real-time charts and technical trading rules can even be monitored on the internet. Taylor and Allen [1992] document the popularity of the trading rules in their survey of currency traders in London.

Technical traders (the users of technical trading rules) and chartists tend to put little faith in strict efficient markets. In defense of a trend following rules, traders describe how prices are influenced by private information, but do not fully reflect it. Prices may even be slow to react to public information. Users claim that technical trading rules provide an indication of when those with the superior information have begun to trade and what position they are taking in the market. With a quick enough response, the technical trader is able to imitate the actions of those with the superior information before the market price completes its adjustment. The opportunity to make a profit is lost if the trader waits to receive the fundamental information, since he will not likely receive it until long after the price adjustment is complete, if at all. The Rendleman, Jones, and Latané [1982] finding that price movement starts before the earnings report is made public and continues to adjust after the reports are made public, lending credence to the technical trader's story.

For this paper, a model is developed and examined in which individual rational optimizing behavior leads to inefficiencies in an asset market which can be exploited through use of a technical trading rule. The objectives for this paper are to explore the profitability of select technical trading rules in the market and to determine the impact of the technical trading rules on the market. The approach examines the aggregate behavior of heterogeneous agents. In the model, each trader individually selects the information source believed to be the most beneficial for the next period of trading. Much of the model is developed analytically, but the final analysis is accomplished through computer simulations.

A number of recent papers employ techniques relevant to this work. Brock and Hommes [1997] and Brock and LeBaron [1996] model endogenous information selection by individual traders. Both papers analyze the market by considering heterogeneous traders and then aggregating within groups of traders. The simulation developed and explored by Arthur *et al* [1997] simulate a small number of individual interacting agents. Both styles of simulation have the traders relying on the past performance as a measure of its future success. The endogenous selection of which information source to use is thus based on past performance. Chiarella and He [1999] explore further the Brock and Hommes environment by examining the impact of different parameters and as well as various potential heterogeneities among traders. Farmer [2000] and

Lux and Marchesi [1998] do not have shifting populations of traders, but instead base each trader's current access to capital on past trading success, which leads to a similar results with regards to the market power of a trading strategy is concerned. Brock and Hommes model a non-durable commodities market, but for the remaining four asset market models, when the market is near equilibrium, profits are made by chance rather than by strategy, which allows the TTR to occasionally earn greater profits than the fundamental information. The resulting shift in market power to the technical trading rules moves the market away from equilibrium and can actually generate patterns which contribute to additional technical trading rule success. One of the primary objective for this paper is to have traders determine whether conditions call for the acquisition of fundamental information based on observations of the current state of the market rather than on past performance. Another objective is to examine the technical trading rules as they are ideally used by traders.

Other papers related to this analysis include models examining the employment of technical trading rules. Using the standard approach of Grossman and Stiglitz [1980], Grundy and McNichols [1989] and Brown and Jennings [1989] employ two rounds of trading in order to examine the information revealed in past prices. Blume, Easley, and O'Hara [1994] work with a similar model, but introduce features to make trading volume a useful statistic. These models, as do many models examining the use of technical trading rules, rely on stationarity of the unknown parameter. With stationarity, a sequence of market generated data provides information on the unknown parameter. The model presented in this paper lacks such stationarity. If the trading rule is to be useful, it must provide information about future realizations of either the market generated price series or of the exogenous dividend series without the aid of convergence to a stable terminal value.

I. The Model

The model is developed with the aim of creating an environment in which market participants reasonably choose to rely on a technical trading rule, at least under certain conditions.

A. The Market

A large but finite number of agents, indexed by $i = 1, ..., N$, trade a risky asset and a risk free bond. Early in time period t, the trader selects which information source he intends to use for the period. Based on the information signal received, the trader purchases $a_{i,t}$ units of the risky asset at price p_t and $b_{i,t}$ units of the risk free bond. The risk free bond, with a price of one, pays R. In period $t + 1$, the risky asset pays a stochastic dividend d_{t+1} and traders sell the asset for the market determined price, p_{t+1}. The dividend follows a random walk:

$$d_{t+1} = d_t + \varepsilon_{t+1}, \qquad (1)$$
$$\varepsilon_{t+1} \sim IIDN(0, \sigma_d^2).$$

The available sources of information are a signal based on fundamental information about the risky asset or to use a technical trading rule (TTR) which provides the investor with a buy or sell indicator based on past and present price patterns.

B. The Fundamental Trader

Traders who choose to receive a signal based on fundamental information are modeled as selecting a portfolio to maximize an exponential utility function conditional on the given information set $H_{i,t}$,

$$\max\{E[-\exp(-\gamma w_{i,t+1}) \mid H_{i,t}]\}$$
$$\text{s.t., } p_t a_{i,t} + b_{i,t} = w_{i,t} \tag{2}$$
$$w_{i,t+1} = (p_{t+1} + d_{t+1})a_{i,t} + Rb_{i,t}.$$

Under the assumption that returns are distributed normally, the demand for the risky asset is the conditional expectation of the excess return to the risky asset divided by γ times its conditional variance:

$$a_{i,t} = \frac{E[p_{t+1} + d_{t+1} \mid H_{i,t}] - Rp_t}{\gamma \operatorname{var}(p_{t+1} + d_{t+1} \mid H_{i,t})}. \tag{3}$$

Were the market price determined solely by the fundamental traders, $p_{t+1} + d_{t+1}$ would have a normal distribution. The normality may no longer be true in a market populated by technical traders, but the demand function will remain the same.[1]

A subset of $H_{i,t}$ is the shared common information set $I_t = \{d_t, p_{t-1}, n_{t-1}, ttr_{t-1}\}$ where n_t is the proportion of the population using the TTR and ttr_t indicates "buy" or "sell" according to the indication of the TTR. Both n_t and ttr_t are developed more extensively below. The private component of $H_{i,t}$ is a signal that provides the recipient with an indication of next period's dividend payment. The individual's private signal, $y_{i,t}$, derives from the following formula:

$$y_{i,t} = d_{t+1} + e_{i,t}, \text{ with } e_{i,t} \sim IIDN(0, \sigma_e^2).$$

A motivating factor for the introduction and use of technical trading rules is the cost of obtaining quality fundamental information. Traders wish to avoid relying on costly information at times when the expected benefits are limited. A cost to acquiring the fundamental information is considered, but found to be unnecessary and provides no additional insight.

[1] LeBaron [1999] suggests thinking of the demand function as maximizing a utility function which closely resembles the negative exponential, but one which very likely no longer exhibits CARA

Recognizing that the private signal is a noisy indicator of the future dividend, the trader's optimal forecast of d_{t+1} relies on a weighted combination of the received signal and the unconditional expectation.

$$E[d_{t+1} | H_{i,t}] = (1 - \beta)d_t + \beta y_{i,t} \qquad (4)$$

with

$$\beta \equiv \text{cov}(d_{t+1}, y_{i,t})/\text{var}(y_{i,t}) = \frac{\sigma_d^2}{\sigma_d^2 + \sigma_e^2}.$$

The combination minimizes the expected squared error of the forecast. Aggregating among the fundamental traders, the mean forecast of d_{t+1} is

$$\frac{1}{(1-n_t)N} \sum_{i=1}^{(1-n_t)N} (1-\beta)d_t + \beta y_{i,t} \rightarrow (1 - \beta)d_t + \beta d_{t+1}.$$

C. The Technical Trader

One easily implemented and commonly computed technical trading rule is a Simple Moving Average trading rule. Each period, the trader computes an average of the price of the risky asset over some extended period, l. This is referred to as the moving average (MA)

$$MA_t = \frac{1}{l} \sum_{s=0}^{l-1} p_{t-s}.$$

The rule provides a "buy" or "sell" signal based on whether the current price is above or below the MA. The time-series created, ttr_t, has a value of 1 in the event that p_t is greater than MA_t (buy) or -1 in the event that p_t is less than MA_t (sell). Placing bands around the moving average, so that users receive a "hold" signal when p_t is between the bands, is known as the Envelope trading rule. For the Envelope rule, assigning $ttr_t = 0$ corresponds to a "hold" signal. Both the

MA and Envelope rules are trend following signals, meaning that they tend to signal "buy" during a price rise and "sell" during a price decline.

The individual trader using the TTR needs a demand function based on the signal. The volume of demand of each technical trader is set to a fixed value, vol^{TR}. The trader using the trading rule has demand

$$a_t^{TR} = vol^{TR} \cdot ttr_t \,. \tag{5}$$

D. Determining the Market Price

Let $\bar{a}_t^F$ and $\bar{a}^{TR}$ represent the period t average demand by fundamental traders and technical traders using the TTR respectively;

$$\bar{a}_t^F = \frac{1}{(1-n_t)N}\sum_{i=1}^{(1-n_t)N} a_{i,t}^F \text{ , and } \bar{a}_t^{TR} = \frac{1}{n_t N}\sum_{i=1}^{n_t N} a_{i,t}^{TR} = vol^{TR} \cdot ttr_t.$$

With supply of the risky asset set exogenously to zero, equilibrium market clearing conditions require

$$0 = (1-n_t)\bar{a}_t^F + n_t \bar{a}_t^{TR} \tag{6}$$

in each period t. In the Walrasian equilibrium, the price is determined to satisfy this condition. In forming expectations of the period's price, fundamental traders conjecture that the price is determined by a linear function of the information underlying the private signals. The idiosyncratic component of the private signals are aggregated away, leaving:

$$p_t = b_{0,t} + b_1 d_t + b_2 d_{t+1} \,. \tag{7}$$

In the posterior, this conjecture is correct. The second two terms of the price equations capture the influence of the fundamental traders who rely on observed dividends and their individual private signals. The coefficients solve to b_1 = (1-β)/(R-1) and b_2 = β/(R-1). The value of the intercept, $b_{0,t}$, reflects the impact of the demand by the group of technical traders, which is time dependent. The solution to $b_{0,t}$ requires the discussion of expectations which follows. The conditional variance solves to

$$V = \text{var}(p_{t+1} + d_{t+1} \mid H_{i,t}) = \frac{\gamma}{(R-1)^2}\left(\sigma_e^2 + \beta^2\right)\sigma_d^2$$

When analyzing the simulations, it will be useful to compare the market clearing price to the price that would have prevailed in the absence of the technical traders. Label this price p^F where

$$p_t^F = b_1 d_t + b_2 d_{t+1}$$

E. The Role of Expectations: Selecting an Information Source

Prior to receiving one's private signal, each trader must select a signal source. The only information available at the time of this decision is the shared public information in I_t. The trader attempts to maximize expected profits, defined as the quantity demanded of the risky asset times the realized excess return of the risky asset over the risk free bond. The expected profit to using the fundamental information sources is thus

$$E[\pi_t^F \mid I_t] = E[a_t^F (p_{t+1} + d_{t+1} - Rp_t) \mid I_t]$$

$$= E\left[\frac{E[p_{t+1} + d_{t+1} - Rp_t \mid H_t]}{\gamma V}(p_{t+1} + d_{t+1} - Rp_t) \mid I_t\right]. \qquad (8)$$

The closed form solution to (8) and $b_{0,t}$ can be obtained by substituting in equations (7) and (4), the public information based expectations, and the solutions for b_1 and b_2. Two possible solutions exist, each of which is demonstrated to be self fulfilling. Under the "continuation" regime, traders anticipate that the distortion in price caused by the technical trading rule persists into the next period. Traders forecast $b_{0,t+1} = b_{0,t-1}$. The expected profit computes to

$$E[\pi_t^F] = (1-R)^2 b_{0,t-1}^2 / V \tag{9}$$

with $b_{0,t} = \frac{n_t a_t^{TR} V}{(1-n_t)(R-1)}$. Expected profits for the fundamental information is greater than or equal to zero, strictly greater than zero when the TTR causes mis-pricing of the security. The expected profit is increasing in the impact of the TTR, but is fairly small due to the prediction that the market price fails to revert to the fundamental price, thus removing the anticipation of a capital gain. The expected profit reflects only the gain from the fact that the price does not properly reflect the expected value of dividend payment.

The "exploitations" regime is based on the traders assuming that any distortions caused by the technical trading rules quickly dissipates. They forecast $b_{0,t+1} = 0$. The result is that the expected profit becomes

$$E[\pi_t^F] = R(R-1) b_{0,t-1}^2 / V, \tag{9'}$$

with $b_{0,t} = \frac{n_t}{(1-n_t)R} a_t^{TR} V$. The magnitude of the profit term is much larger than under the continuation regime because the traders anticipate a capital gain from the market's return to p^F.

The expected profit from using the fundamental information source is compared to the performance evaluation of the technical trading rule. Traders use a weighted average of the past performance of the trading rule to form an estimate of its success in the present period. This is not all that odd a stipulation since the advice of technical trading rule practitioners is to look for and consider using rules that have recently performed well.[2]

$$E_t[\pi_t^{TR}] = \nu\pi_{t-2}^{TR} + (1-\nu)E_{t-1}(\pi_{t-1}^{TR}), \tag{10}$$

where ν indicates the weight placed on the most recent observations of profits.[3]

As a way of introducing heterogeneity, the individual trader's final choice is modeled as a randomized discrete choice in the nature of Manski and McFadden [1981] and Anderson, de Palma, and Thisse [1992]. Applying the LLN to the individual probabilities, the proportion of the population choosing each signal is equal to the probability that individual traders choose that signal. Thus,

$$n_t = \frac{\exp(\rho E_t[\pi_t^{TR}])}{\exp(\rho E_t[\pi_t^{TR}]) + \exp(\rho E_t[\pi_t^{F}])} \tag{11}$$

is the proportion of the population using the TTR in period *t*.

The greater the expected benefit of one signal over the other, the higher the proportion of traders who choose to use that signal. How sensitive the population is to differences in the expected profits is set according the "intensity of choice" parameter, ρ.[4] The greater the value of ρ, the greater the sensitivity of traders to differences in expected profits of each signal. With ρ → ∞, small differences in the expected profits lead to large population shifts towards the source with the greater expected profit for the period. In this case, the model choice approaches full rationality. With ρ set to zero, differences in the expected profits are ignored. The population of

[2] For example, major software packages popular among traders for tracking charts and technical trading rules actively promote a feature which automatically informs the user which of the rules tracked in real-time have recently performed well.
[3] The *t*-2 profit is the most recently observed. The *t*-1 profit has yet to be determined since the time *t* price is, as yet, undetermined.
[4] Setting ρ identifies the standard deviation of randomized component of the individual agent's expectations of profit.

traders split evenly between the information options, regardless of which has the higher expected profit.[5]

Once traders select their information source for the period, individual signals are received. Equation (3) indicates how the fundamental traders use their expectations of excess returns to determine a demand function. Equation (5) indicates the shared demand of the technical traders. All traders submit their demand function to the market. The market price for the risky asset, p_t, is determined to clear the aggregate demand. The period ends with traders carrying out their transactions, selling their holdings from the previous period and purchasing their portfolio to hold into the next period.

II. Simulation Results

Without a computable solution, computer simulation is necessary for examining the model and the impact of the TTR on the market's behavior. The objective is to determine which situations produce profitable outcomes for the TTR and for the fundamental information, what characterizes these situations, and how they arise. The important control parameters are the intensity of choice parameter, ρ, and in selecting the regime. The TTR employed in this examination is a five period moving average rule with no bands. Examining different length MA and envelope rules all produce results similar to those presented in this paper. The following parameters settings are kept unchanged: $\gamma = 1$, $R = 1.02$, $\nu = 0.3$, and $vol^{TR} = 0.0001$; also $\sigma_d^2 = 1$ and $\sigma_e^2 = 1$ which yields $\beta = 1/2$.

[5] The "base" population proportions can be adjusted by employing weights in equation 11. In general, decreasing the base n reduces the impact of the TTR on the market and increases the TTR's profitability.

The following sections examine the model, first by examining the impulse response generated by the simulated market to a shock in dividends, and then by examining the time-series generated from the random dividend process.

A. Impulse Response

Set $\varepsilon_\tau = 1$ and $\varepsilon_t = 0 \, \forall \, t \neq \tau$ in order to examine the market impact of a one time shock. Figures 1a-1c and 2a-2c plot the impulse response of a number of important variables under the continuation and exploitations regimes respectively. The shock occurs at $\tau = 5$. The top frame plots two price series. The solid line is the market clearing price, p_t. The dashed line is the value as perceived by the aggregate of the fundamental traders, p_t^F. The middle frame shows the average profits for the group of traders. The solid line depicts π_t^F and the dashed line π_t^{TR}. The bottom frame plots the proportion of the population using the TTR, n_t.

[Insert Figure 1 about here]

Consider first the continuation regime and a low level of ρ. Figure 1a is the extreme with ρ = 0. The population is insensitive to expected profits and thus n_t remains at 1/2. In the period before the shock, $p_{\tau-1}^F$ reflects a portion of the perfect foresight adjustment because the fundamental trader's forecast of d_τ combines $d_{\tau\text{-}1}$ and d_τ. The price increase at τ-1 triggers a "buy" signal from the TTR. The final market clearing price at τ-1 is $p_{\tau-1} \geq p_{\tau-1}^F$. The inflated price is necessary to induce the fundamental traders to sell to the technical traders.

At time τ, with d_t revealed, p_τ^F completes the adjustment to the new equilibrium. The same size population of technical traders continue to receive the same buy signal leading to the same price distortion in period τ as in τ-1. This ensures a capital gain for the TTR in τ-1. Even in the absence of the continued deviation, had p_τ = p^F_τ, the TTR still earns a profit because, under the current setting, the inflated $p_{\tau\text{-}1}$ remains below p^F_τ. The result is that the technical traders pay less than the realized value for the risky asset. This result is sensitive to vol^{TR} since increasing vol^{TR} increases the magnitude of the price deviation and could push $p_{\tau\text{-}1} > p^F_\tau$.

With a fixed population, and in the absence of additional shocks, the TTR continues to issue a buy signal for a time equal to the length of the MA. When the TTR stops signaling "buy", the subsequent price decline results in a switch to a "sell" signal, which is the beginning of a pattern of oscillation around stable p^F. In this particular examination, the market dynamics are straight forward due to the fixed n_t.

Set ρ to 300, as in Figure 1b, and the population responds to differences in the expected profit of each information sources. The positive profits from the buy position taken in period τ-1 are realized in period τ and first influences the population proportion at time τ+1 by increasing $E_t(\pi^{TR}_{\tau+1})$. Also in time τ and τ-1, the fundamental traders observe a distortion in the price, but, as discussed, under the continuation regime they do not anticipate a return to p^F. So the magnitude of the expected profit is very small, particularly when compared to the recently realized profits of the TTR. Thus, in τ+1, n_t increases as traders are attracted to the TTR. The TTR continues to signal "buy". The additional technical traders force the market price to increase further resulting in $p_{\tau+1} - p^F_{\tau+1} > p_\tau - p^F_\tau$. This market behavior constitutes a price bubble. Despite a leveling off of the fundamental value, the price continues to rise as the population of traders shifts towards the use of the TTR.

The larger the ρ setting, the greater the number of traders who shift towards using the TTR. If large enough, the resulting capital gain can produce enough profits for the TTR to attract a further increase n_t for period τ+2, as in Figure 1c, where $\rho = 1000$. The price bubble feeds off of the continued realized profits of the TTR. The continued profits earned by the TTR depend on the capital gains resulting from the price bubble. The relationship is symbiotic. The bubble collapses when the population growth fails to produce the necessary profits to counter the losses from overpayment for the realized dividend. How large and how quickly a bubble develops is based on ρ. At extraordinarily large values of ρ, n_t quickly approaches one after the shock to dividends. Having reached the limit, the bubble also quickly collapses, but only because of the inability to attract more traders to continue the bubble's growth. The collapse back to fundamentals is neither anticipated, nor intentionally exploited by the fundamental traders.

During a bubble's growth, the technical traders earn positive profits at the expense of the fundamental traders. When the bubble collapses, the fundamental traders share the windfall.

[Insert Figure 2 about here]

Under the exploitation regime, the price deviation is substantially smaller than under the continuation regime. Though subject to the same level of noise in the private signal, the fundament traders in the exploitation regime are much more willing to sell shares of the risky asset at a price just slightly greater than p^F than are traders under the continuation regime. This stems from the anticipation of being able to profit from the market's return to p^F. At $\rho = 0$, except for the smaller deviation from the fundamental price, the market behaves essentially the same as under the continuation regime, as revealed by Figure 2a. In Figure 2b with $\rho = 300$, a barely discernable bubble develops for period τ+1. The τ-1 price is greater than the fundamental price, but remains substantially less than the realized p_τ. The TTR population increases because the realized profit earned by the TTR proves more attractive to traders than is the anticipation of the capital gains expected from the minor adjustment back to the fundamental value.

A large increase in ρ is required to alter the pattern of the market response to the shock. In Figure 2c, with ρ = 2000, the population shifts towards the TTR after the initial profit realization. With the large price deviation that results, the fundamental information becomes attractive. The shift back corrects the market price, reducing the need to use the fundamental information so that the population reverts to the TTR. The population and price oscillate until the impact diminishes. Increasing ρ further simply increases the magnitude, but the oscillations remain diminishing.

Each of the two regimes is self fulfilling. Under the continuation regime, the fundamental information is much less attractive to traders, even when a deviation from p^F is perceived. Further, traders who do collect the fundamental information trade under the assumption that prices will not return to the fundamental value, the resulting in no market pressure to move the market price towards p^F. Under the exploitation regime, traders anticipate a benefit to knowing the fundamental value if they suspect a deviation from p^F. In addition, those traders who obtain an indicator of next period's dividend trade aggressively to exploit the anticipated capital gain from the return p^F. Such aggressive trading tends to succeed in keeping the market price near p^F.

B. Market Simulations

The market is examined by running simulations based on the random dividend process. The simulations presented consists of 10,000 periods. The two simulations displayed in Figures 3 and 4 are representative of the continuation and exploitations regimes when subjected to the same set of random socks. For these figures, a new frame is include that plots p_t - p_t^F . The parameter ρ is set to 300 for both. As suggested by the impulse response examinations, the price deviations are substantially larger in magnitude under the continuation regime than under the exploitation regime.

[Insert Figure 3 about here]

[Insert Figure 4 about here]

A pattern that stands out is how the price bubbles develop during trends in p^F (which are the result of trends in d_t). In Figure 3, the bubbles tend to grow in magnitude as the trend continues, collapsing when the trend stops or reverses. The trends contribute to the realized profits of the TTR. The profits feed the popularity of the TTR which feeds the growth in the price bubbles, particularly in the continuation regime. The end result is that the market price amplifies any trend in the underlying intrinsic value. This outcome suggests that the price is subject to fads or overreaction as discussed by Shiller [1981], Shiller [1990], and De Bondt and Thaler [1990], among others. The following section further investigates the stability of the trend induced bubbles.

As with the impulse response the TTR earns a profit during the bubble's growth at the expense of the fundamental traders. At the bubble's collapse, the fundamental traders share in the capital gains. The profits can be seen in the third frame of both figures 3 and 4.

[Insert Figure 5 about here]

The horizontal axis of Figure 5 runs from zero to one and the vertical axis is the average profits earned by a hypothetical trader who switches from the fundamental to the TTR information only if the population proportion, n_t, surpasses the indicated value. Thus, the trader on the far left of the scale relies on the TTR exclusively since all observations of n_t are greater than zero. On the far right is the trader who relies exclusively on the fundamental information even as n_t approaches one.

The average profit earnings suggested by both Figures 5a and 5b are consistent with the impulse response analysis. The trader who relies exclusively on the TTR earns average positive profits, exploiting the fact that the purchase price at the start of a bubble remains close to p^F and below the realized value after the bubble collapses. The trader who relies on the fundamental information exclusively earns positive average profits for larger values of ρ, but negative profits for low values of ρ.

With only two groups of traders, one group's profits in a given period are made at the expense of the other group. When there is little or no shift in the population proportion, the positive average profits for the TTR, requires negative average profits for the fundamental information. With a shifting population proportion, the timing of the gains and losses becomes important. At the beginning of a price bubble, the proportion of the population using fundamental information is relatively high (keeping the price near p^F). As the bubble grows, this proportion falls. By the time the bubble collapses, the population using the fundamental information is relatively small. Figure 6 plots the relationship between n_t and the magnitude of the price bubble. The larger the price bubble the fewer users of the fundamental information. Though the total market wide fundamental trader profits from the bubble's collapse is less than the total loss during its rise, the losses are spread among many traders while the profits are concentrated among the thinned population that remains. The individual fundamental traders profits during a price bubble's collapse can be exceptionally large when $1-n_t$ is particularly small.

The trader in the middle, who switches from fundamental information to the TTR after the TTR demonstrates success, suffers the greatest losses. This trader tends to be a fundamental trader during the bubble's development and then switches to the TTR for the bubbles collapse, earning negative profits throughout.

Under the continuation regime, if vol^{TR} is large enough that $p_{\tau-1} > p^F_\tau$, then even at a bubble's inception, the technical traders tend to over pay for the security based on the realized value. Increasing vol^{TR} shifts the curves in 5a so that on the left, $\overline{\pi}^{TR} < 0$, and on the right, $\overline{\pi}^{F} > 0$, even at low ρ for the continuation regime. In the exploitation regime, the impact of the technical traders on price is so minimal that vol^{TR} would have to be set unreasonably large in order to make the TTR unprofitable.

[Insert Figure 6 about here]

C. Repeated shocks

A reasonable interest is in how the trend induced price bubbles behave. Do they only collapse when the trend stops or reverses, or would they collapse on their own if given enough time? Is the stability of the bubbles different for the continuation and exploitation regimes? In order to better understand the situation, a continuous series of shock is examined by setting $\varepsilon_{\tau+k} = 1$ for $k \geq 0$, zero otherwise. As with the impulse response analysis, $\tau = 5$.

[Insert Figure 7 about here]

Examining the continuation regime, Figure 7a displays the results of a relatively low $\rho = 100$. The top frame plots the market price deviation, $p_t - p_t^F$. The middle and lower frames plot profits and n_t. The figure suggests that the n_t increases to a stable n* and a fixed $(p_t - p_t^F)^*$. At this steady state, the buy signal of the TTR earns a positive profit, indicating $p_{t+1} + d_{t+1} - Rp_t > 0$. Further, the profit earned by the TTR is sufficiently large to exceeds the expected profit of using the fundamental information.

Figure 7b captures how with the elevated ρ, the momentum of the TTR profits causes the population increase to surpass n^*. At the elevated level, the realized TTR profits are insufficient to support the population of technical traders, though the TTR profits remain positive. The proportion drops down to n^*. The stable n^* appears to be an increasing function of ρ, which is consistent with the greater "intensity of choice" parameter.[6]

Increase ρ to ρ = 800, as in Figure 7c, and the market experiences dampening oscillations around n*. Increase ρ further and the oscillations become explosive, as demonstrated in 7d with ρ = 860. When this occurs, the particularly small population of fundamental traders that remains by the time the bubble collapses realize enormous individual profits.

[Insert Figure 8 about here]

Under the exploitation regime, the smaller price deviation tends to keep the asset price below the realized value. At ρ = 100, the observed time series are similar to the continuation regime. Figure 8a demonstrates that, as with the continuation regime, n_t and (p_t - p_t^F) converge to stables values. In the exploitation regime, stabilization of the market away from the p^F requires that the profit earned by the technical traders competes against expected profits from the exploitation of a price collapse. In contrast to the continuation regime, this requires that the price deviation remains small which keeps the expected profit from a return to p^F sufficiently small. In Figure 8b, increase ρ to 600. As with 7b, the population increase to surpass n^*, but rather than generating a dampening oscillation towards a stable n^*, the oscillations explode until the population alternates just short of the extremes of $n_t = 0$ and $n_t = 1$.

Even with n_t near 1, the distortion to the price is too small to produce profits for the fundamental traders. For the price oscillation to generate profits for the fundamental traders requires further increase in the intensity of choice, as in 8c where ρ = 1300.

[6] That n^* is an increasing function of ρ can be demonstrated using numerical analysis.

III. Concluding Remarks and Further Study

Because fundamental information gathered through individual research provides the trader with a noisy signal of a security's intrinsic value, the trader must temper his forecast by incorporating publicly available information. As a result, market prices reflect only a portion of the news which generates the individual signals. The price does not fully adjust to private information until it becomes public. A trend following technical trading rule is a tool which can exploit this situation by signaling periods of transition.

The technical trading rule performs best when the market price is set by the fundamental traders. Two situations keep the market price near the fundamental price. Either, the popularity of the technical trading rule is limited through low intensity of choice so that the popularity of the technical trading rule cannot reach a level where it overly distorts the price, or the impact of the technical trading rule on price is held in check by the fundamental traders. This latter condition, by keeping the market price near the fundamental value, creates the somewhat counterintuitive result that the technical trading rule performs best when the market works hard to exploit any perceived deviations from the fundamental price.

Whether or not it is beneficial to exploit price deviations is self fulfilling. If traders overwhelmingly choose not to, then deviation from the fundamental value remain and the choice is correct. If the traders overwhelmingly choose to aggressively trade on deviations, the market corrects and, again, the trader's behavior is correct.

Price bubbles develop in situations where the technical traders influence the market price. As a price bubble grows, it increases the profit earned by the TTR, contributing to additional growth in the population using the TTR and further development of the price bubble; a symbiotic relationship. The price bubbles also tend to magnify the movements of the asset's intrinsic value.

Preliminary examinations provide direction for continued research. A price dividend rule in which the user "sells" in the event that the p/d ratio exceeds a threshold value is useless in the market dominated by fundamental traders. Once the MA technical traders enter the market, their influence on the price makes such a rule profitable. The impact of a population of traders using a price dividend rule on the market and on the profitability of the MA rule deserve further investigation. The possibility that each rule in the market spawns a pattern that previously did not exist, and that can be profitably exploited by a new rule provides a good foundation for market analysis employing pattern recognition programs or genetic algorithms for technical trading rule creation and destruction.

References

Anderson, Simon P., André de Palma, and Jacques-François Thisse, 1992. *Discrete Choice Theory of Product Differentiation* (MIT Publishers, Cambridge, MA.).

Arthur, W. Brian, John H. Holland, Blake LeBaron, Richard Palmer, and Paul Tayler, 1997. "Asset Pricing Under Endogenous Expectations in an Artificial Stock Market," in W.B. Arthur, D. Lane, and S.N. Durlauf, eds., *The Economy as an Evolving, Complex System II* (Addison-Wesley, Menlo Park, CA) pp. 15-44.

Blume, Lawrence, David Easley, 1984, "Rational Expectations Equilibrium: An alternative Approach," *Journal of Economic Theory*, 34, pp. 116-129.

Brock, William A., and Cars H. Hommes, 1997. "Rational Routes to Randomness," *Econometrica*, 65(5), pp. 1059-1095.

Brock, William, Josef Lakonishok, and Blake D. LeBaron, 1992. "Simple Technical Trading Rules and the Stochastic Properties of Stock Returns," *The Journal of Finance*, 47(5), pp. 1731-1764.

Brock, William A., and Blake D. LeBaron, 1996. "A Dynamic Structural Model for Stock Return Volatility and Trading Volume," *The Review of Economics and Statistics*, 78(1), pp. 94-110.

Brown, David P., and Robert H. Jennings, 1989. "On Technical Analysis," *The Review of Financial Studies*, 2(4), pp. 527-551.

Chiarella, Carl, and Xue-Zhong He, 1999. "Heterogeneous Beliefs, Risk and Learning in a Simple Asset Pricing Model," Quantitative Finance Research Group Research Paper 18 (August).

De Bondt, Werner F.M., and Richard H. Thaler, 1990. "Do Security Analysts Overreact?" *The American Economic Review*, 80(2), pp. 52-57.

De Long, J. Bradford, Andrei Shleifer, Lawrence H. Summers, Robert J. Waldmann, 1990. "Positive Feedback Investment Strategies and Destabilizing Rational Speculation," *Journal of Finance*, 45(2), pp. 379-395.

Farmer, J. Doyne, 1998. "Market Force, Ecology, and Evolution," working paper.

Grossman, Sanford J., and Joseph E. Stiglitz, 1980, "On the Impossibility of Infomationally Efficient Markets," *The American Economic Review*, 70(3), pp. 393-408.

Grundy, Bruce D., and Maureen McNichols, 1989. "Trade and the Revelation of Information through Prices and Direct Disclosure," *The Review of Financial Studies*, 2(4), pp. 495-526.

Hellwig, Martin, 1982. "Rational Expectations Equilibrium with Conditioning on Past Prices: A Mean-Variance Example." *Journal of Economic Theory*, 26, pp. 179-312.

LeBaron, Blake, W. Brian Arthur, Richard Palmer, 1999. "Time series Properties of an Artificial Stock Market." *Journal of Economic Dynamics and Control*, 23, pp. 1487-1516.

Lux, Thomas, Michele Marchesi, 1998. "Volatility Clustering in Financial Markets: A Micro-Simulation of Interacting Agents," Projektbereich B, Discussion Paper No. B-437.

Manski, C.F., and D. McFadden, 1981. *Structural Analysis of Discrete Data with Econometric Applications* (MIT Press, Cambridge, MA.).

Rendleman, R., C. Jones, and H. Latané, 1982. "Empirical Anomalies Based on Unexpected Earnings and the Importance of Risk Adjustments," *Journal of Financial Economics*, 10(3), pp. 269-287.

Shiller, Robert J., 1981. "Do Stock Prices Move Too Much to be Justified by Subsequent Changes in Dividends?" *American Economic Review*, 71(3), pp. 421-436.

Shiller, Robert J., 1990. "Speculative Prices and Popular Models," *The Journal of Economic Perspectives*, 4(2), pp55-65.

Taylor, Mark P., and Helen Allen, 1992. "The Use of Technical Analysis in the Foreign Exchange Market," *Journal of International Money and Finance*, 11, pp. 304-314.

Figure 1: Impule Response, continuation regime

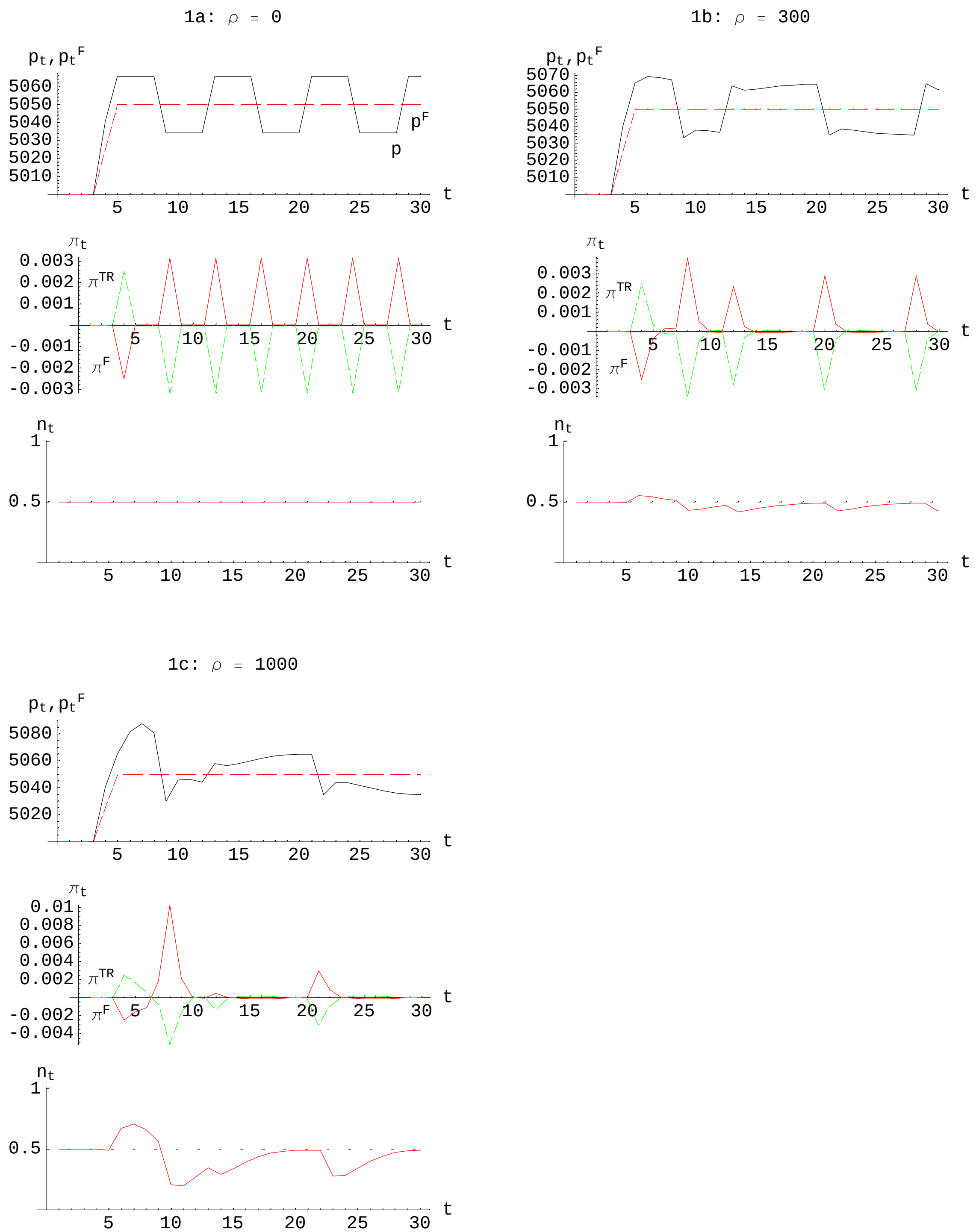
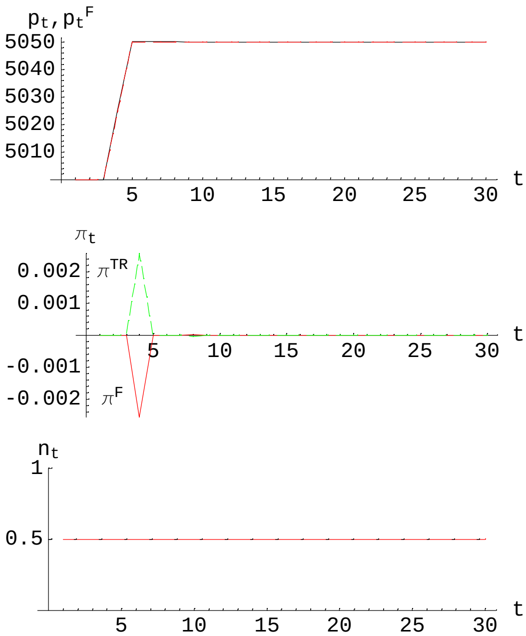
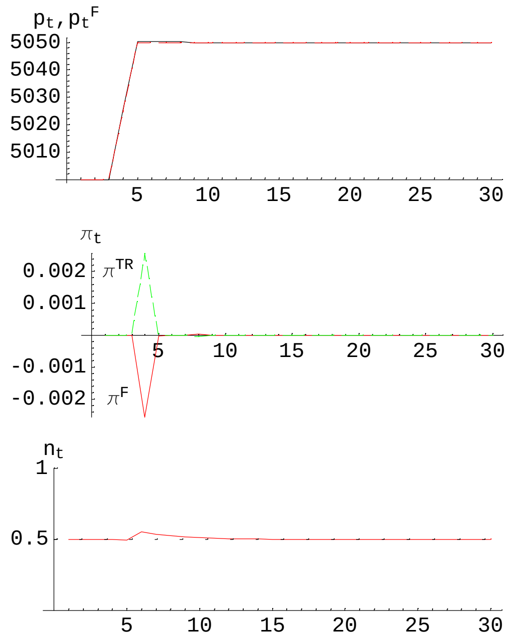


Figure 2: Impule Response, exploitation regime

2a: ρ = 0



2b: ρ = 300



2c: ρ = 2000

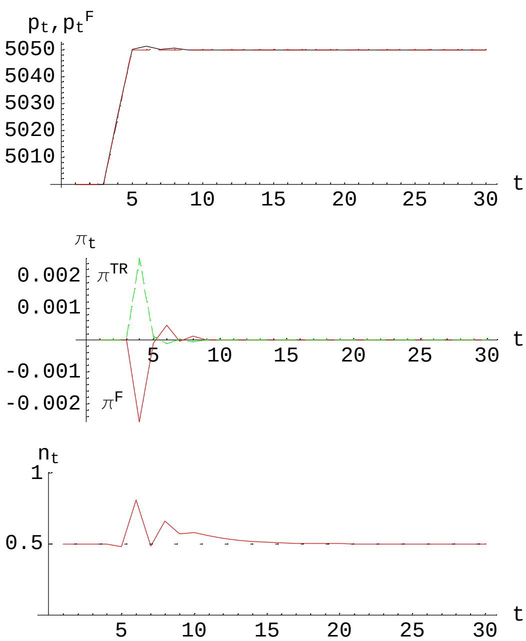


Figure 3: Sample Time Series from Simulation, Continuation regime,   = 300

Figure 4: Sample Time Series from Simulation, Exploitation regime,   = 300

Figure 5: Average profits according to propensity to use Fundamental Information

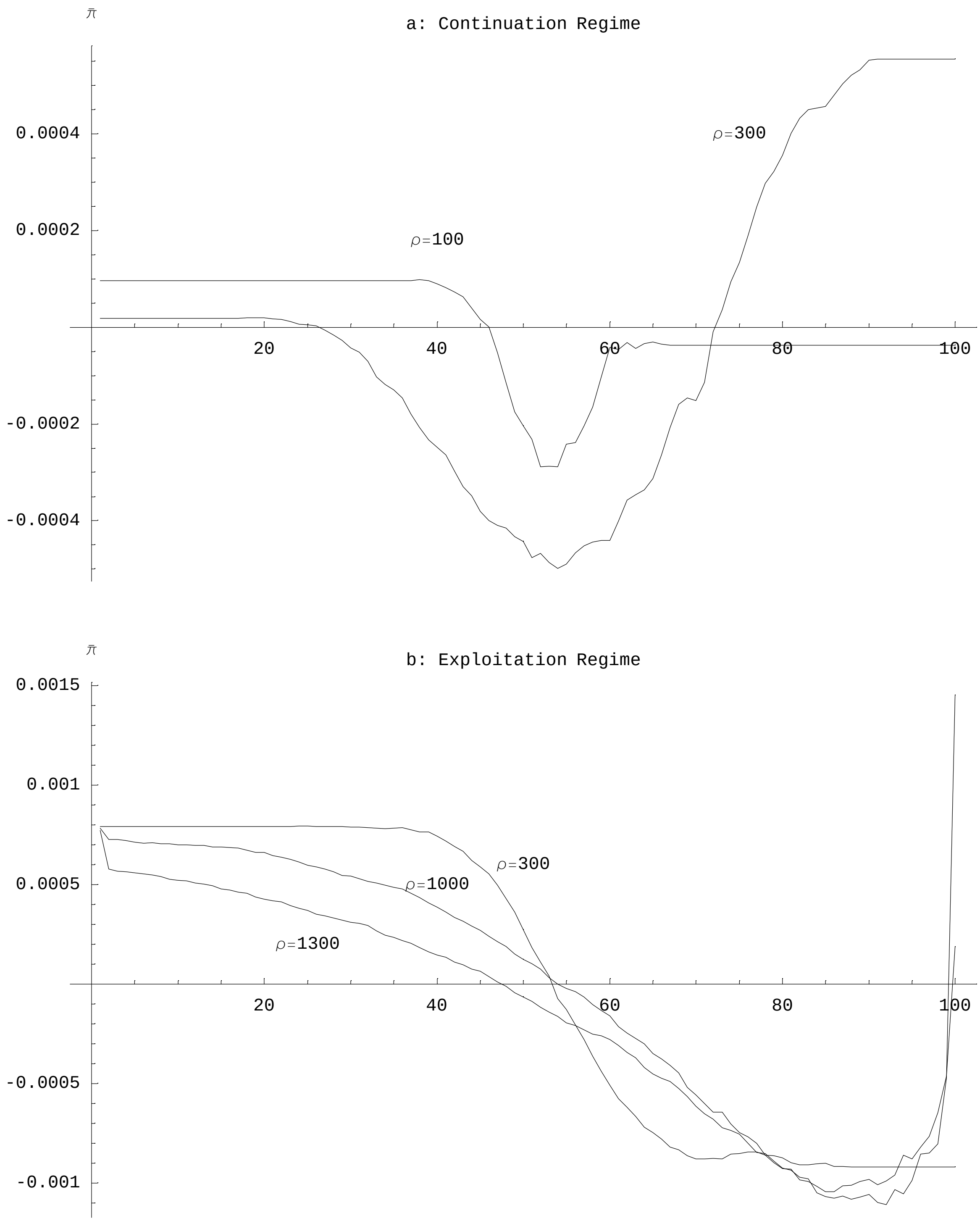


Figure 6: Price deviation vs proportion of population using the TTR, Continuation and Exploitation regimes

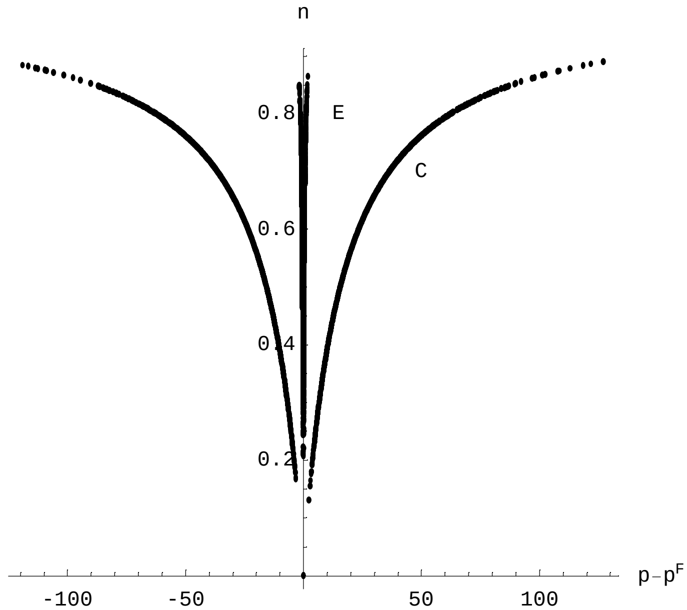


Figure 7: Repeated shocks, continuation regime

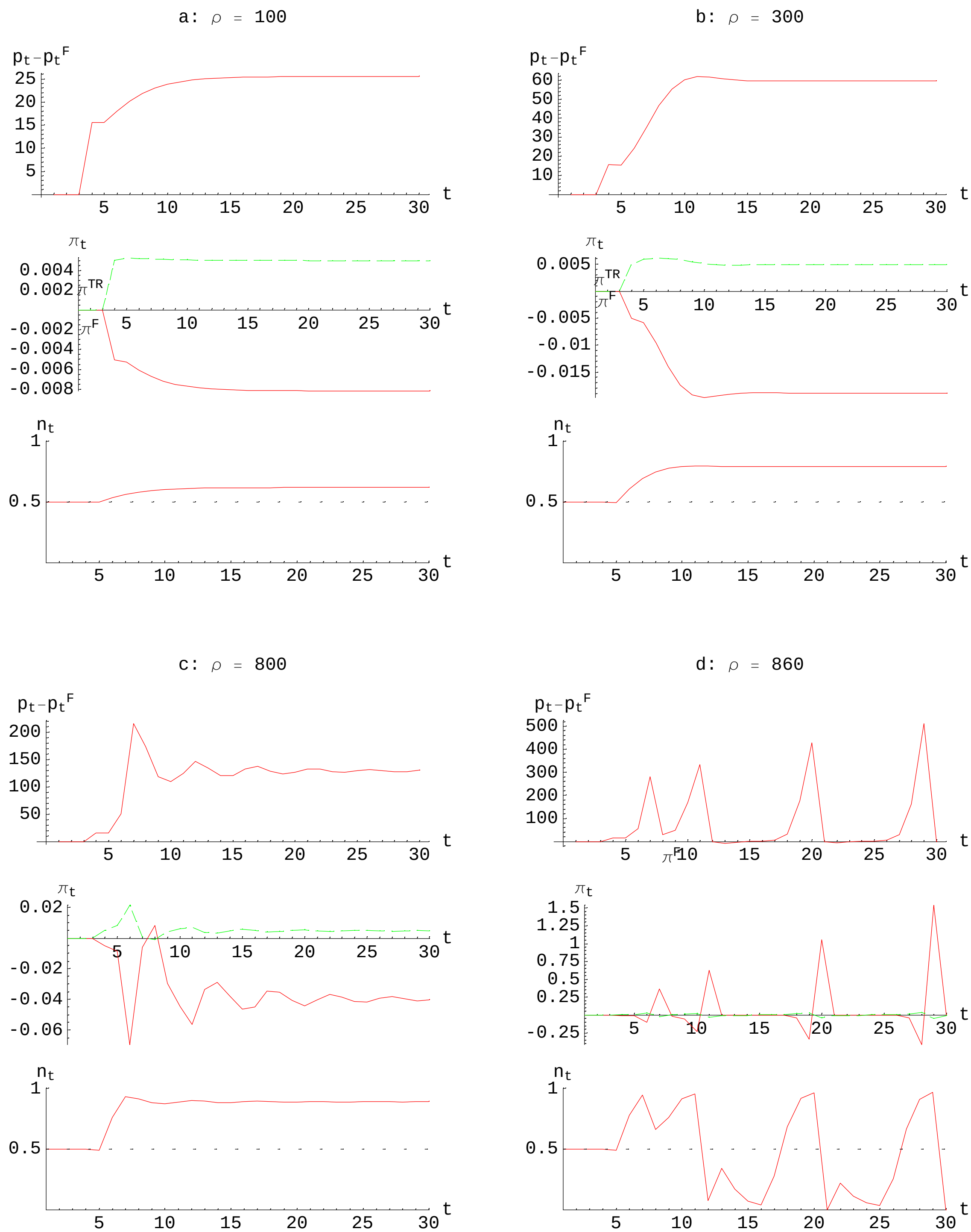


Figure 8: Repeated shocks, exploitation regime