Animal Spirits in the Foreign Exchange Market

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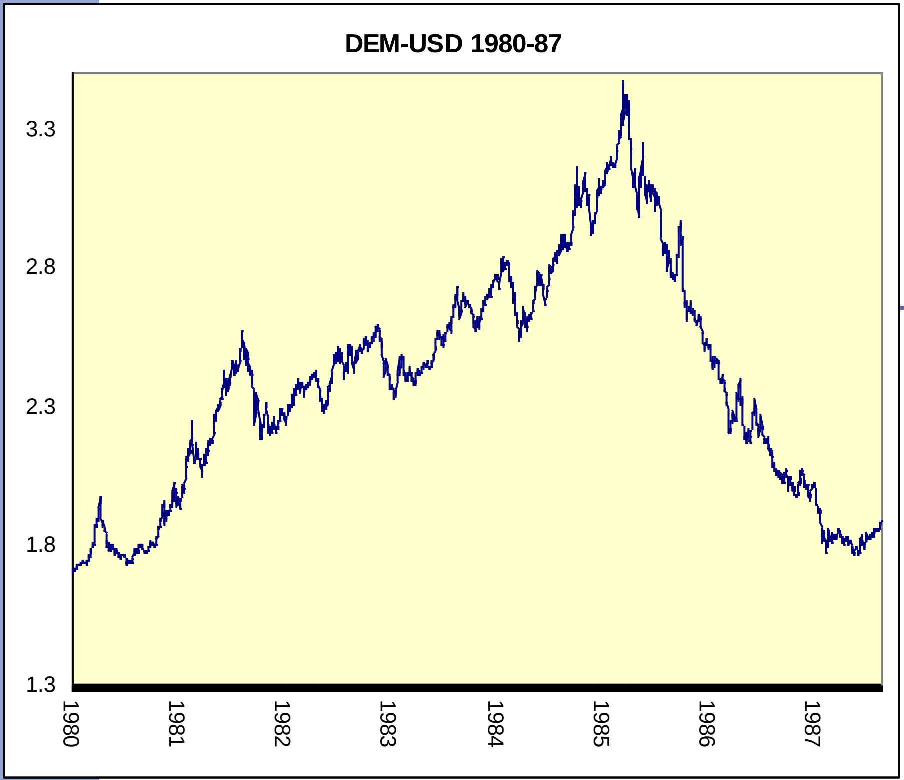
Introductory remarks

- Exchange rate modelling is still dominated by the rational-expectations-efficient-market (REEM) paradigm:
  - Agents continuously maximize utility in intertemporal framework
  - Forecasts are rational, i.e. take all available information into account, including the one embedded in the model
  - Markets are efficient: prices reflect all relevant information

Cracks in the REEM Construction

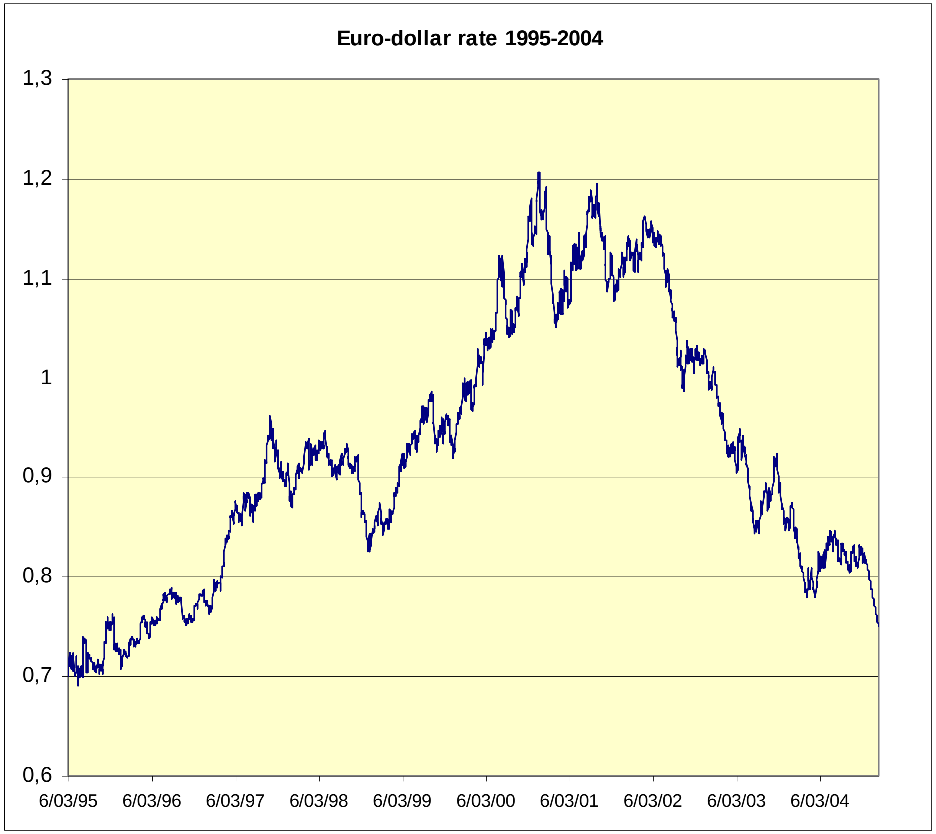
- One of the predictions is that exchange rates can only change because of news in the fundamentals.
- This prediction must surely be rejected



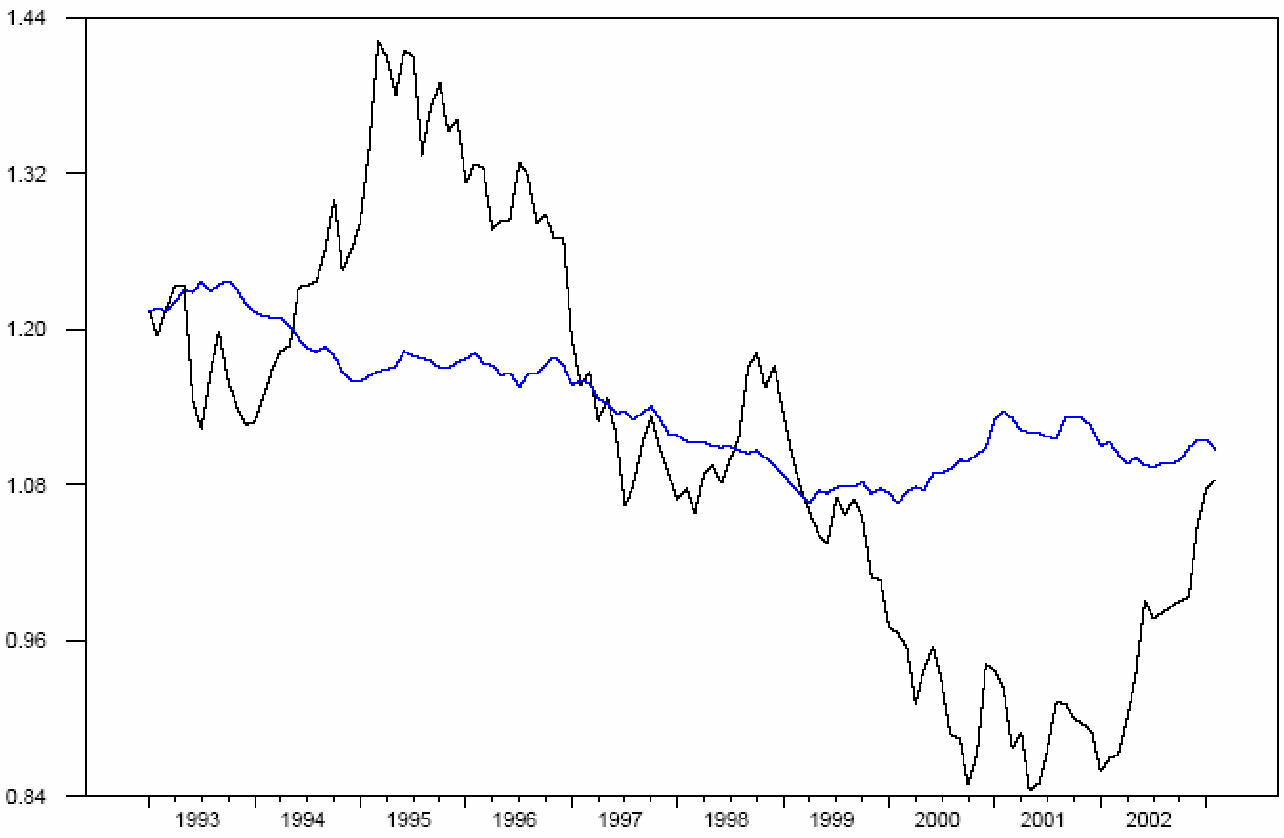
Since 1980 dollar has been involved in bubble and crash scenarios more than half of the time

News model can only explain this by first a very long series of positive news followed by long series of negative news

There is just not enough news to do the trick



Dollar-DM/euro exchange rate, market and fundamental, 1993-2003



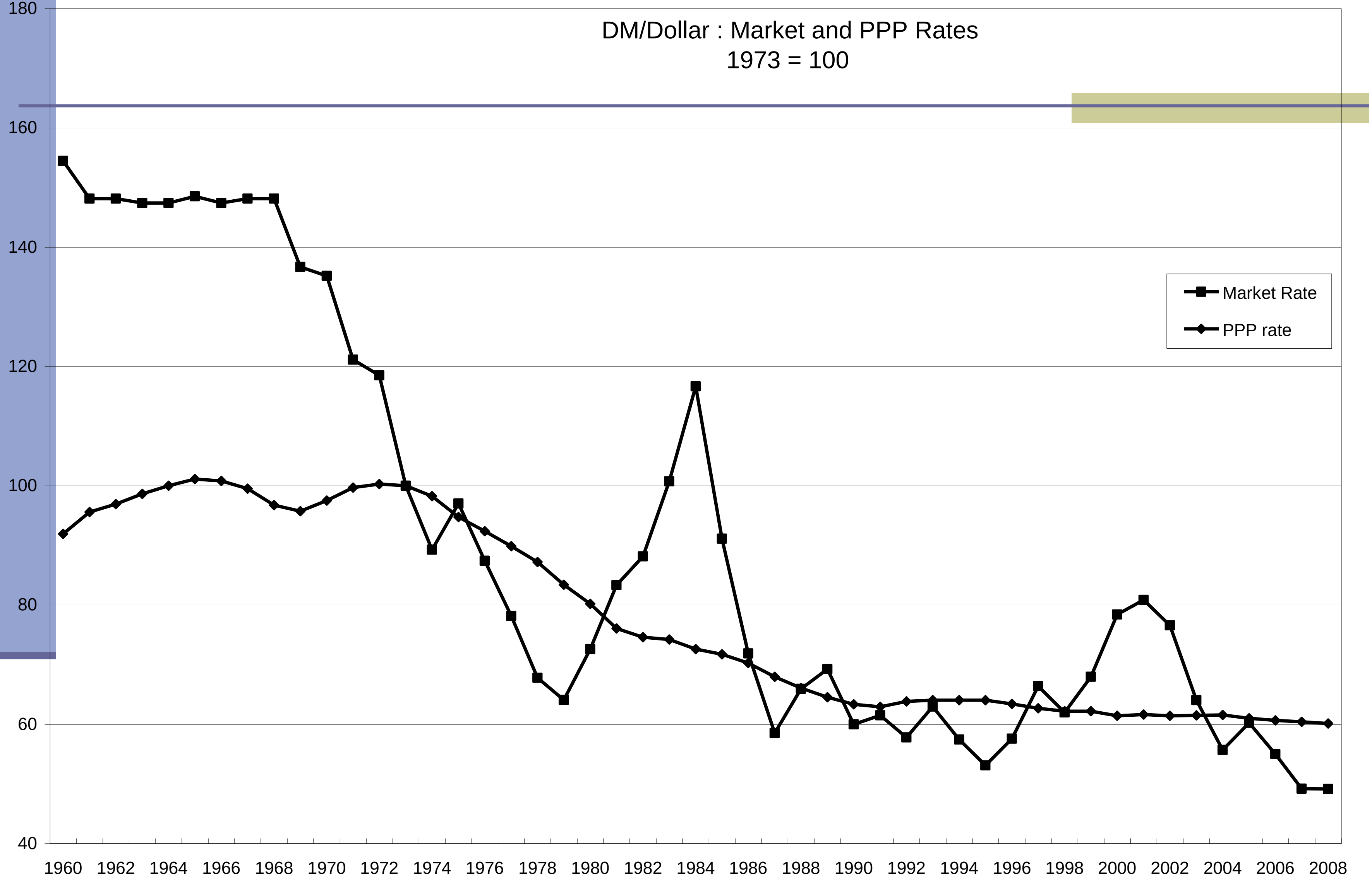
Source: Ehrmann, M., and Fratzscher, M., Exchange Rates and Fundamentals: New Evidence from Real-time Data, forthcoming in Journal of International Money and Finance, 2004

Not only is there not enough positive and later negative news

Quite often the news and the exchange rate move in opposite direction (cfr. 1999-2001)

Other studies have confirmed that most of the time the exchange rate has changed in the absence of observable news

- Previous graph also shows another empirical anomaly:
- Exchange rate is disconnected from underlying fundamentals most of the time
- This is the disconnect puzzle
- Spectacular example: failure of PPP


DM/Dollar : Market and PPP Rates
1973 = 100
Market Rate
PPP rate
180
160
140
120
100
80
60
40
1960
1962
1964
1966
1968
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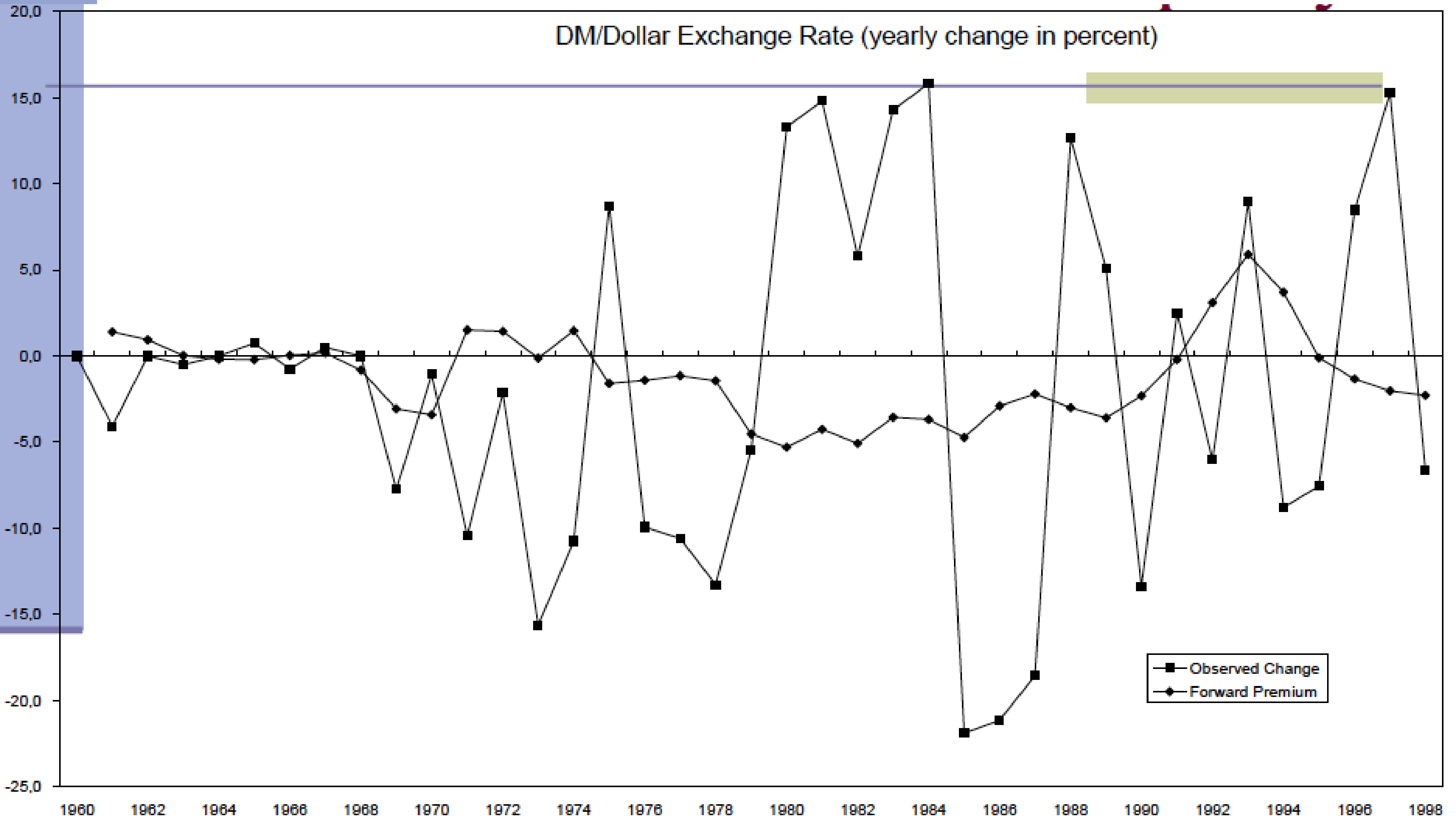
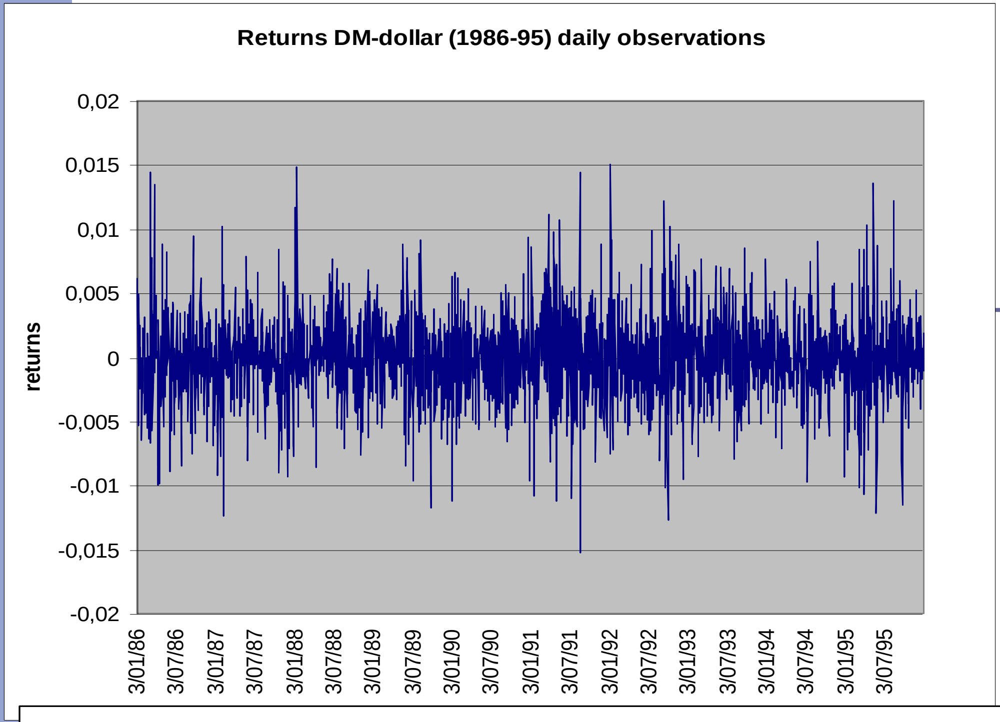
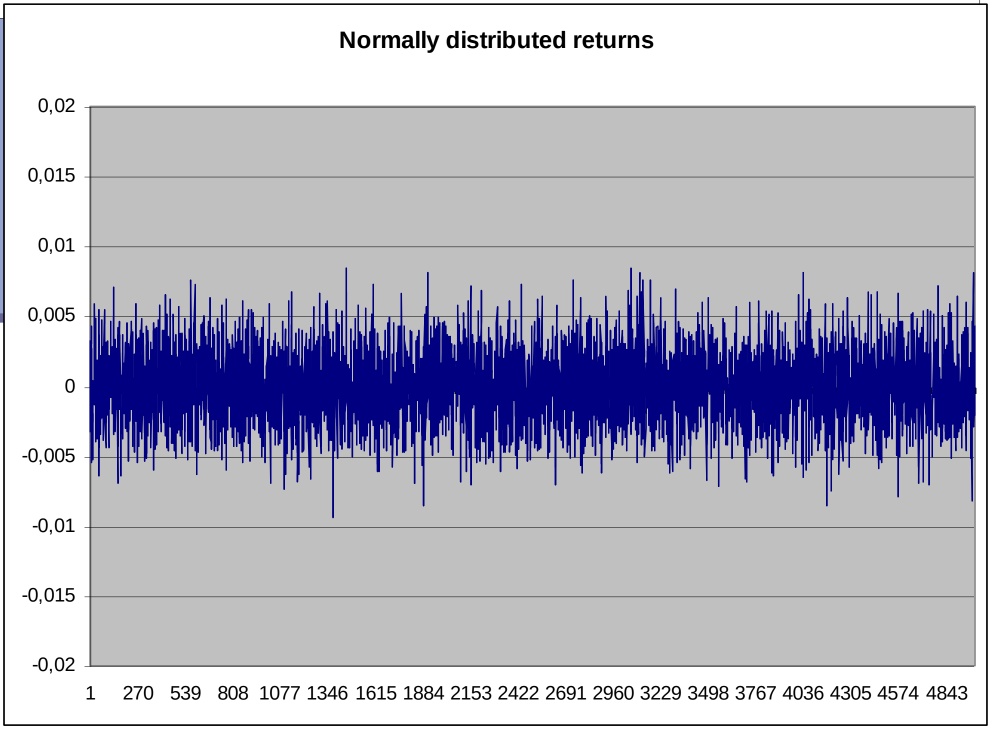
2008

Failure of uncovered interest parity



- There are other anomalies that cannot be explained by the REEM-model
  - Fat tails and excess kurtosis
  - Volatility clustering





Sharp spikes and

Clustering of volatility

There are five spikes that exceed 5 standard deviation

One such spike should be observed only once in 7000 years if exchange rate changes are normally distributed.

- These phenomena can only be "explained" in the news model by assuming that fat tails and volatility clustering is present in the news itself
- This is not an explanation. It shifts the need to explain to another level
- The REEM-model must be rejected on empirical grounds
- Only reason why economists continue to use this paradigm is its internal consistency and its elegance
- In science, esthetic criteria should not guide the selection of models

- Implicit in the REEM model is the view that agents (at least some of them) understand the structure of the underlying model and that they use this information to make predictions
- This means that some agents can store and process in their individual brains the full complexity of the information lying out there in the world.
- An extraordinary assumption
- Such an extraordinary assumption should only be used if it leads to powerful empirical predictions
- The fact is that it does not.

Alternative APPROACH: behavioural finance tradition

- Agents have a limited capacity for understanding and processing the complex available information (bounded rationality).
  - In order to cope with the uncertainty they use relatively simple behavioral rules (heuristics).
  - This does not mean they are irrational.
  - Because the world is so complex it is pointless to try to understand its full complexity
- Rationality in the model is introduced by assuming that agents are willing to learn. They follow a procedure that allows them to evaluate the simple rules

- Two such procedures have been proposed
  - Statistical learning
  - Fitness learning
- We follow the second procedure:
  - Agents compare the rule they currently use to alternative rules
  - They decide to switch to the alternative if it turns out that this is more profitable (fitness criterion; evolutionary dynamics).
- This procedure is also a disciplining device: we have to avoid that all simple rules are possible; there must be a selection mechanism that only keeps the best rules

A behavioural model

- Consists of three blocks
  - Optimal portfolio based on mean variance utility maximisation
  - Expectations formation of heterogenous agents : simple behavioural rules
  - Deciding about the forecasting rules: fitness criterion

1. Mean variance utility maximization

Utility function of agent type *i* who has the choice between domestic and foreign asset

$$U(W_{i,t+1}) = E_t(W_{i,t+1}) - \frac{1}{2}\mu V_i(W_{i,t+1})$$

Wealth constraint

$$W_{i,t+1} = (1+r^*)s_{t+1}d_{i,t} + (1+r)(W_{i,t} - s_t d_{i,t})$$

Optimal holdings of foreign assets

$$d_{i,t} = \frac{(1+r^*)E_{i,t}(s_{t+1}) - (1+r)s_t}{\mu\sigma_{i,t}^2}$$

Aggregation process to derive market clearing exchange rate

$$d_{i,t} = \frac{\left(1+r^{*}\right)E_{i,t}\left(s_{t+1}\right)-\left(1+r\right)s_t}{\mu\sigma_{i,t}^{2}}$$

$$d_{i,t} = \frac{RE_{i,t}\left(s_{t+1}\right)-s_t}{\mu\sigma'^{2}_{i,t}}$$

$$where$$

$$R = \frac{1+r*}{1+r}$$

$$\sigma'^{2}_{i,t} = \frac{\sigma_{i,t}^{2}}{1+r}$$

Aggregating individual demands:

$$\sum_{i=1}^{N} n_{i,t} d_{i,t} = D_t$$

Equilibrium demand and supply:

$$Z_t = D_t$$

Market clearing exchange rate:

$$s_t = \left(\frac{1+r^*}{1+r}\right) \frac{1}{\sum_{i=1}^{N} \frac{w_{i,t}}{\sigma_{i,t}^2}} \left[\sum_{i=1}^{N} w_{i,t} \frac{E_t^i\left(s_{t+1}\right)}{\sigma_{i,t}^2} - \Omega_t Z_t\right]$$

2. Expectations formation

Fundamentalists' forecast: negative feedback

$$E_{f,t}\left(\Delta s_{t+1}\right) = -\psi\left(s_{t-1} - s^{*}_{t-1}\right)$$

Chartists' forecast: positive feedback

$$E_{c,t}\left(\Delta s_{t+1}\right) = \beta \sum_{i=1}^{T} \alpha_i \Delta s_{t-1}$$

3. Learning the forecasting rules: fitness criterion (discrete choice theory)

- Agents face discrete choice
- They are boundedly rational
- Utility has deterministic and random component
- This setup allows to derive fraction of agents choosing fundamentalist and chartist rules

Learning the forecasting rules: fitness criterion (discrete choice theory)

$$w^{\square}_{c,t} = \frac{exp\left[\gamma \pi'_{c,t-1}\right]}{exp\left[\gamma \pi'_{c,t-1}\right] + exp\left[\gamma \pi'_{f,t-1}\right]}$$

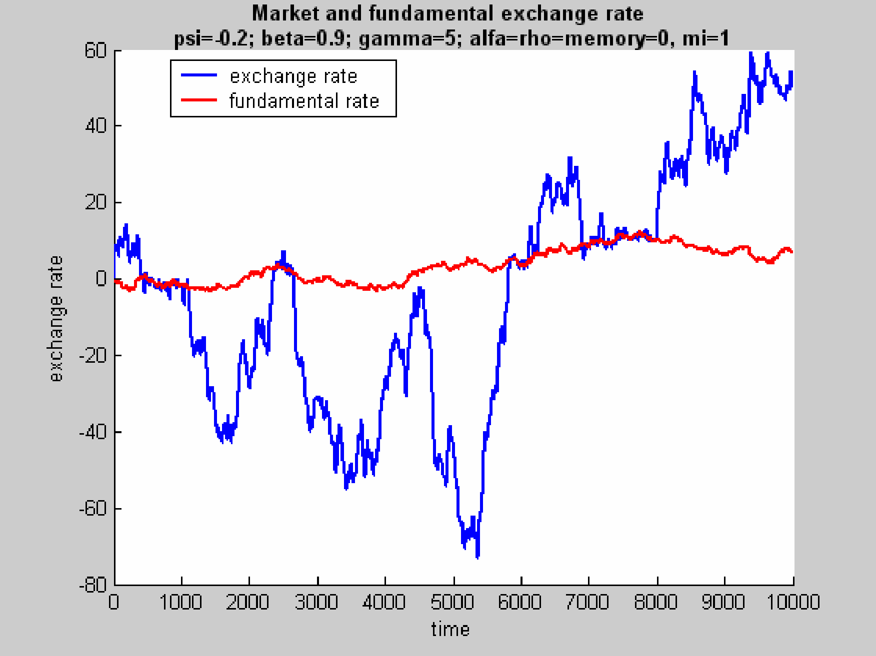
$$w^{\square}_{f,t} = \frac{exp\left[\gamma \pi'_{f,t-1}\right]}{exp\left[\gamma \pi'_{c,t-1}\right] + exp\left[\gamma \pi'_{f,t-1}\right]}$$

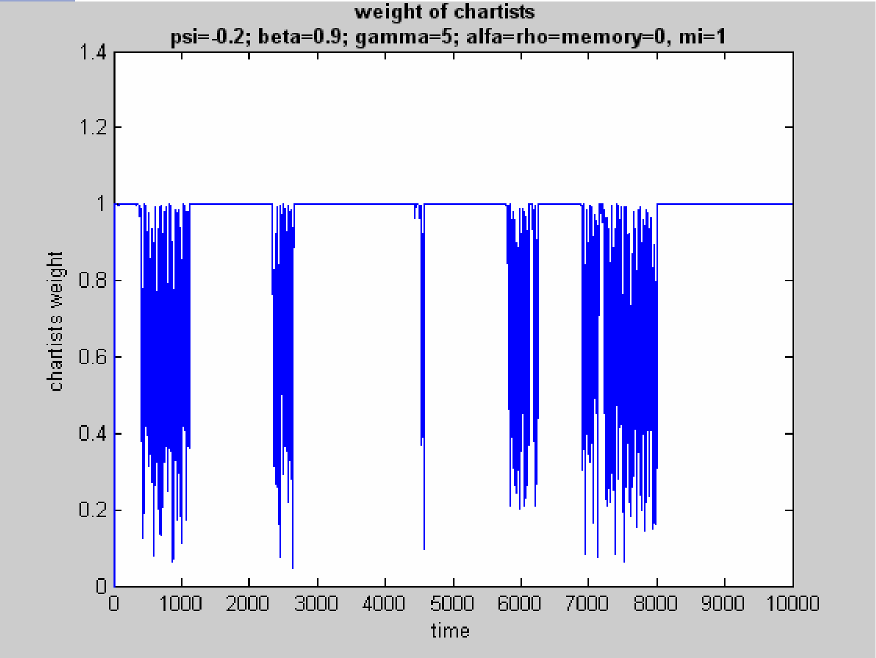
$$\pi'_{c,t-1} = \pi_{c,t-1} - \mu\sigma^2_{c,t-1} \text{ and } \pi'_{f,t-1} = \pi_{f,t-1} - C - \mu\sigma^2_{f,t-1}.$$

- switching is determined by relative risk-adjusted profitability
- Note: there is learning in the model; it is not "statistical learning" (Sargent(1993))
- we use risk-adjusted profits; risk is time varying and is measured by the forecast errors of using the forecasting rule

Stochastic simulations

- Non-linear structure of the model does not allow for a simple analytical solution
- We use numerical methods
- We first show some examples of simulations of model in time domain
- Remember: fundamental exchange rate is random walk

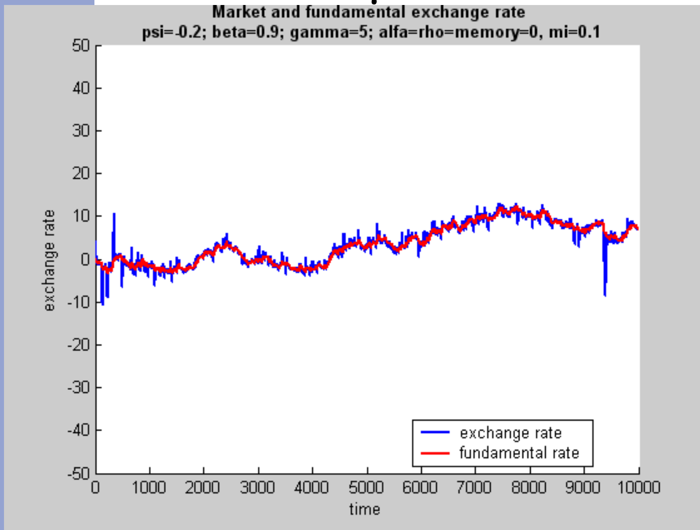




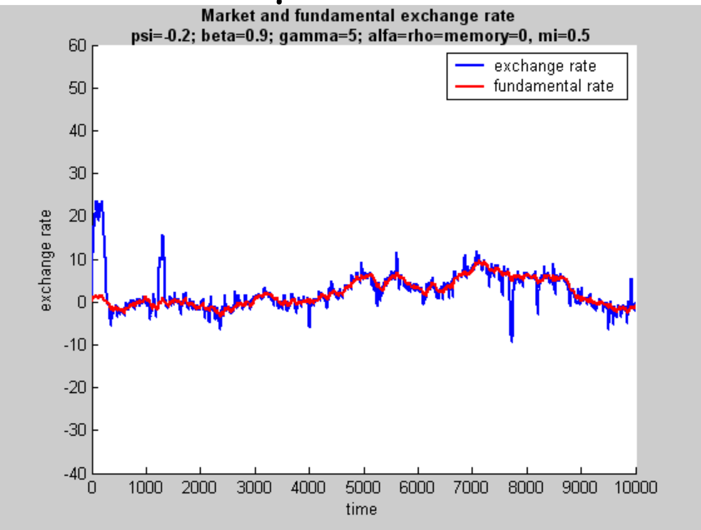
- Model predicts that exchange rate is disconnected from fundamental much of the time
- Periods during which exchange rate closely follows fundamental alternate with periods when exchange rate is disconnected from fundamentals
- The latter are periods during which technical traders completely dominate the market
- It appears that sometimes fundamentals matter at other times they do not.

Different degrees of risk aversion μ

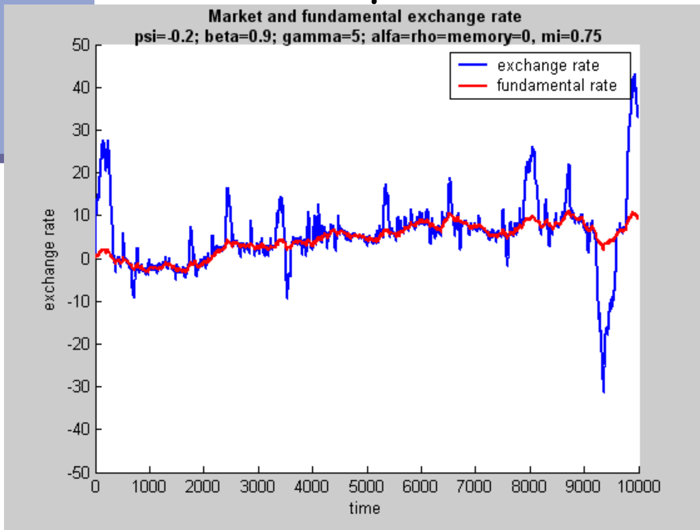
μ=0.1



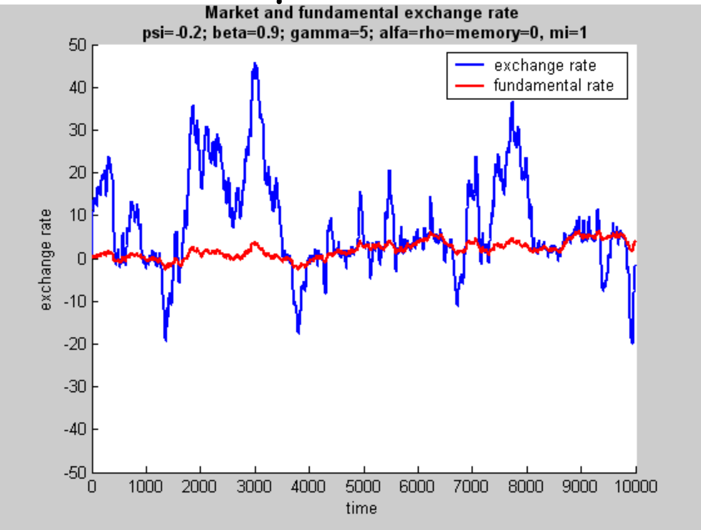
μ=0.5



μ=0.75



μ=1

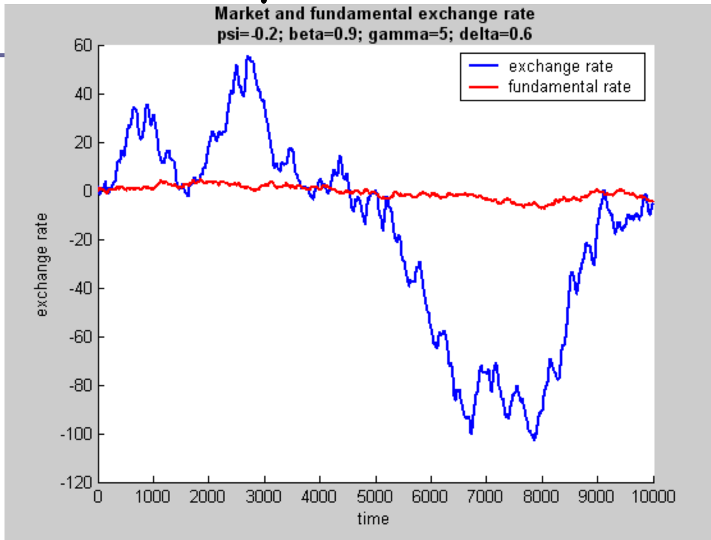


When risk aversion increases exchange rate departs from fundamental more persistently

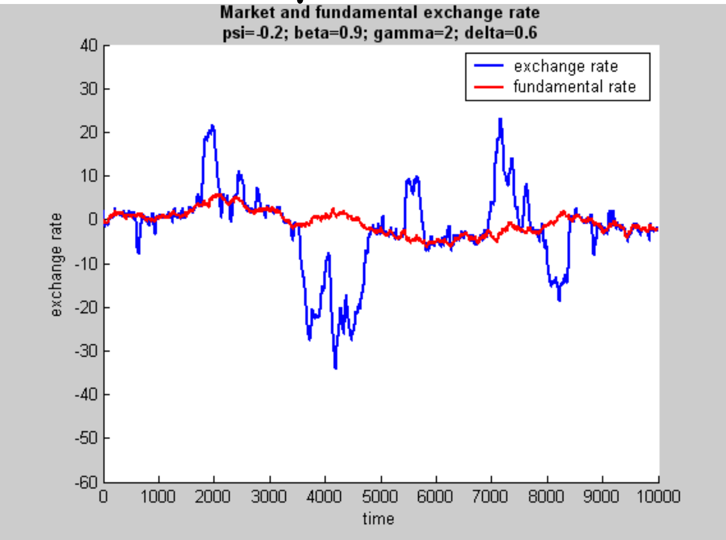
There is a failure of arbitrage when agents are too risk averse

Different gamma (sensitivity of switching with respect to profitability)

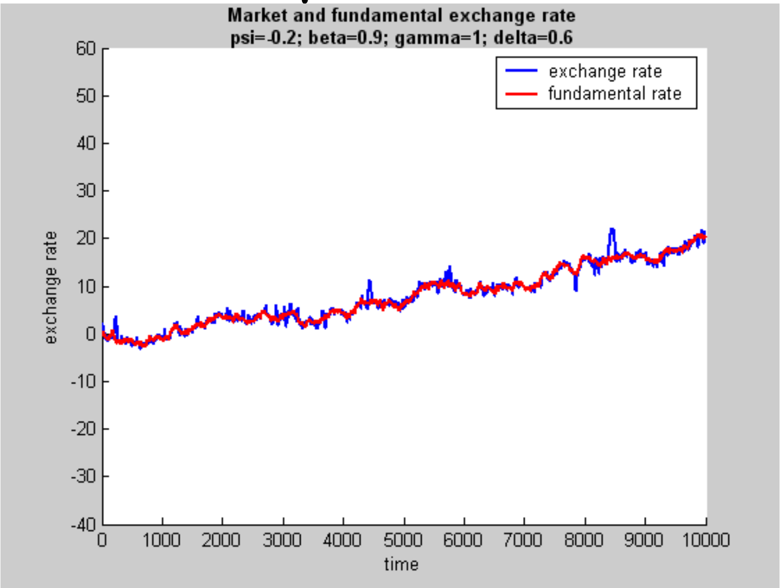
$\gamma = 5$



$\gamma = 2$



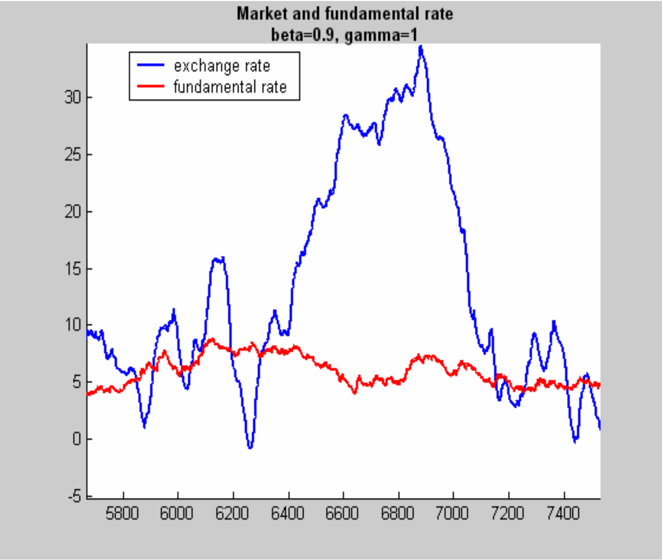
$\gamma = 1$

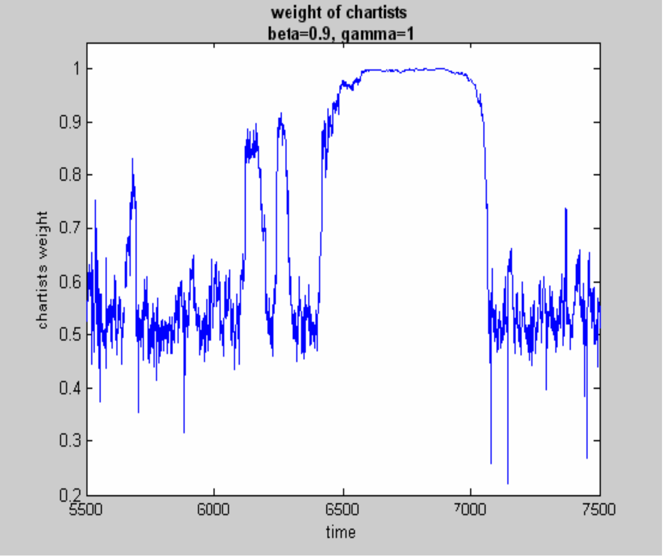


Model creates bubbles and crashes. The anatomy of bubbles and crashes

- First, self-fulfilling increase in relative profitability of technical trading and self-fulfilling decline in relative risk of technical trading
- Second, this dynamics reaches its limit when (almost) everybody has become a technical trader.

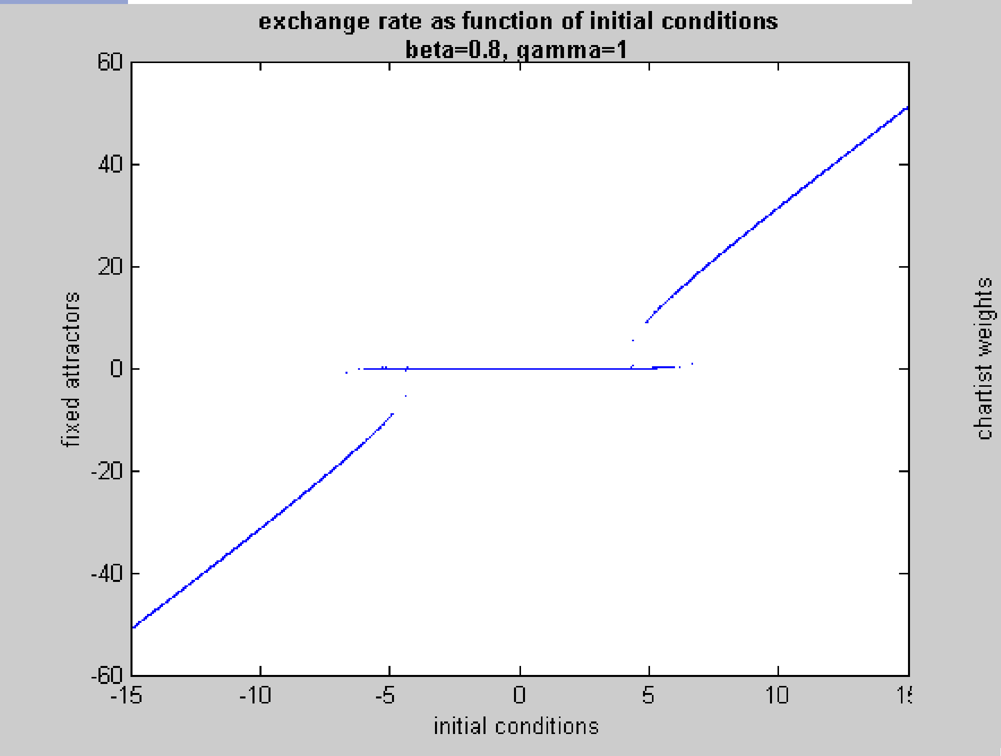
  Technical trading's profitability slows down.
- Third, an exogenous shock, e.g. in the fundamental can lead to a crash
- Technical traders' share is brought back to normal level of tranquil market.
- Asymmetry in bubble and crash

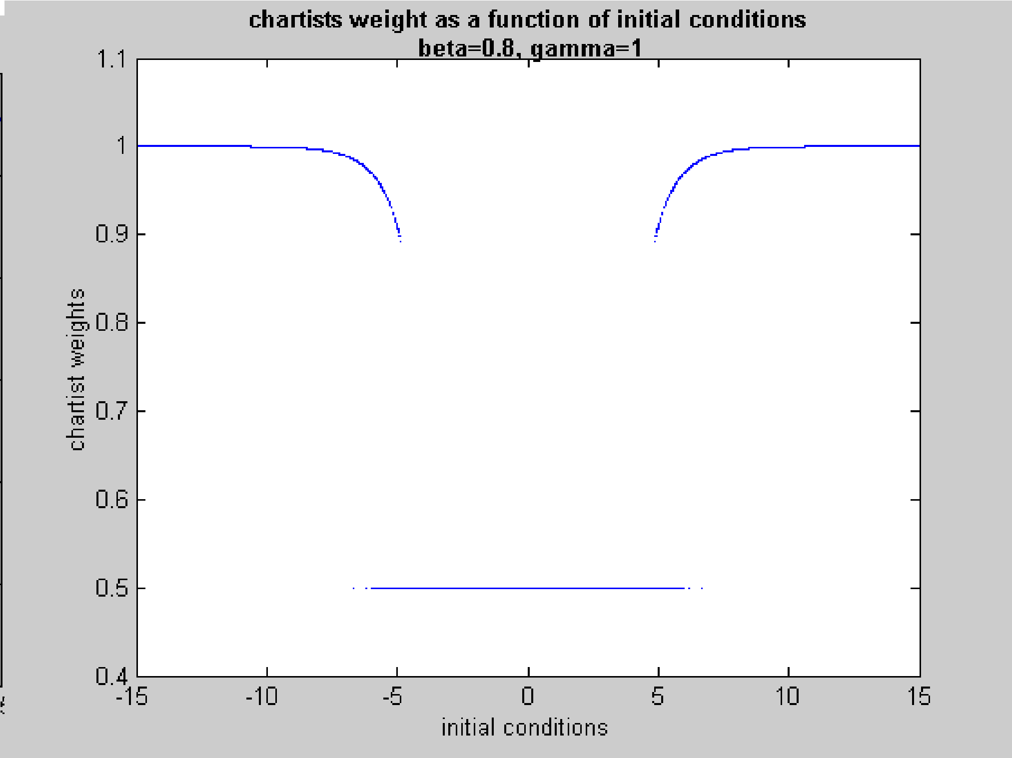




- In order to understand the nature of the results we analyse the deterministic part of the model

Deterministic solution



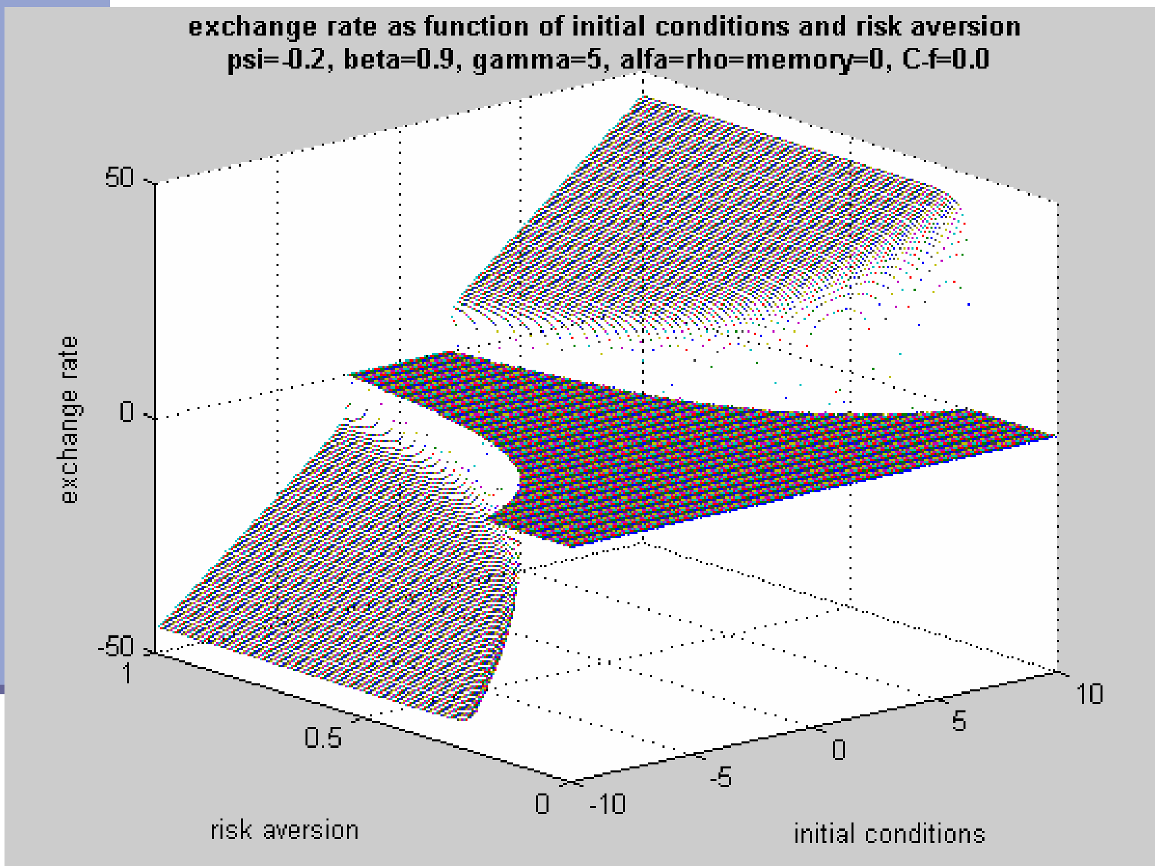


- Two types of attractors.
  - Small disturbance: Fundamental attractor.
  - Large disturbances: Non-fundamental ("bubble") attractors.

- Small disturbances:
  - exchange rate converges to fundamental rate
  - weight of technical traders and fundamentalists are equal to 50%.
  - Their expectations are model-consistent

- For large initial disturbances
  - Exchange rate converges to non-fundamental (bubble) attractor
  - Technical traders' weight converges to 1.
  - Absence of fundamentalists eliminates the mean reversion dynamics.
  - Technical traders' expectations are model-consistent

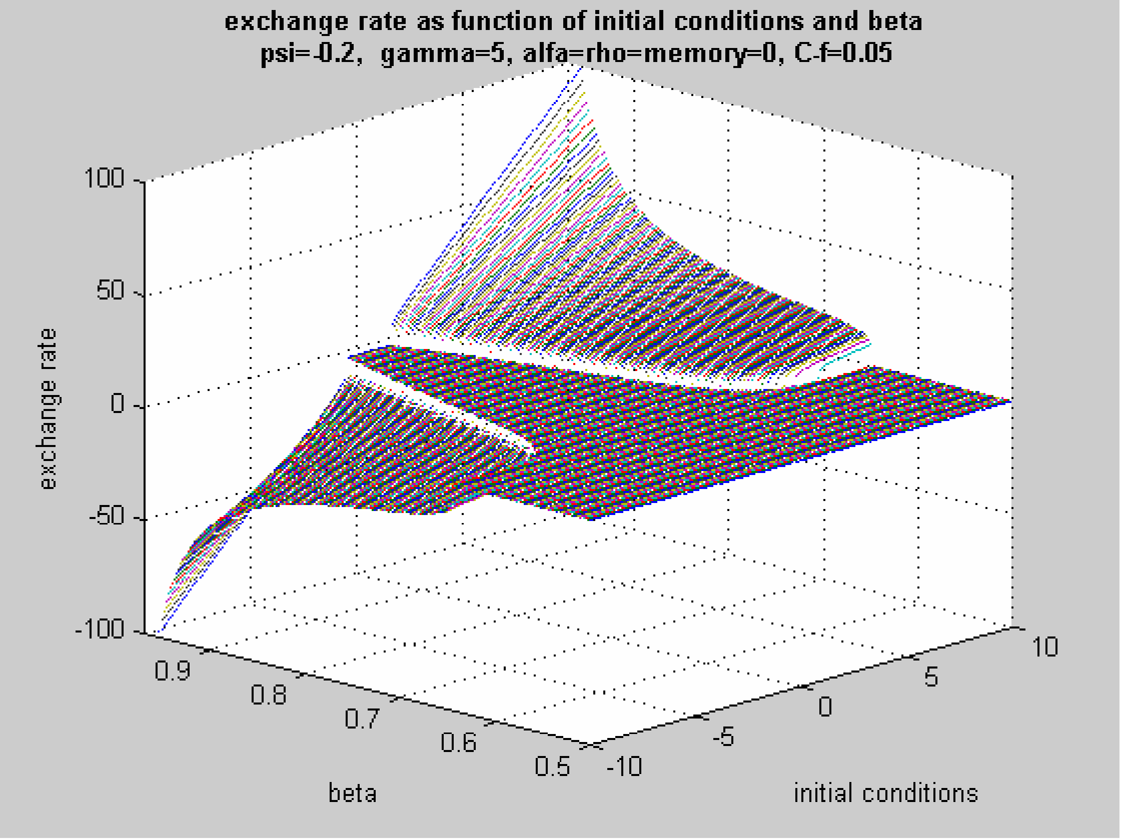
Risk aversion and the nature of equilibria



- When agents have low risk aversion (they perceive risk to be low and the world to be stable) only fundamental equilibria. This is an environment in which agents stick to their beliefs
- When agents have high risk aversion (they perceive risk to be high and the world to be highly uncertain) there are fundamental and non-fundamental equilibria. This is an environment in which agents easily switch to other beliefs (forecasting rules)

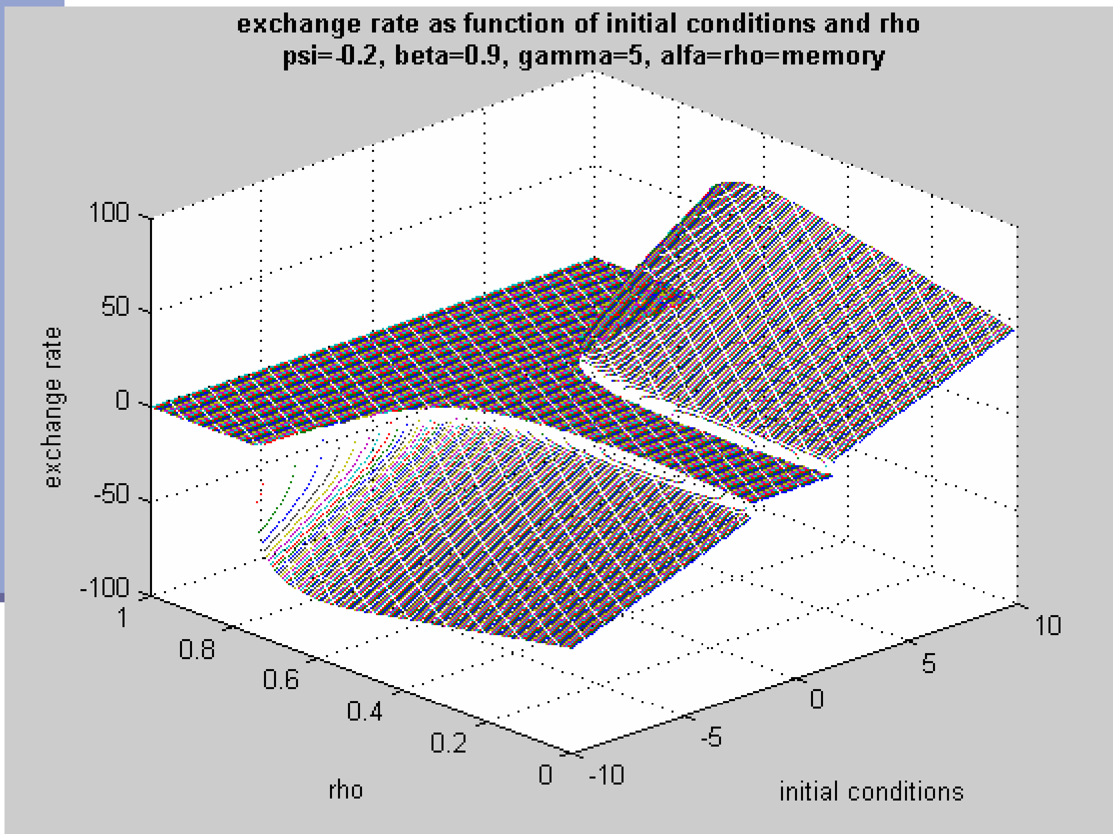
- One possible interpretation of these results:
- When fundamentalists are very risk averse, they will not be willing to exploit the profit opportunities that arise when a bubble develops.
- There is a failure of arbitrage
- As a result, the mean reverting forces triggered by fundamentalists are weak and we have many bubbles (and crashes)
- Conversely when fundis have low risk aversion they are willing to exploit these profits during bubble
- Thus bubbles (non-fundamental equilibria) arise because of a failure of arbitrage.

Technical traders' extrapolation and the nature of equilibria



- As beta increases zone of fundamental equilibria shrinks
- Beta measures strenght of extrapolative forecasting
- Smaller shocks lead to bubble equilibria
- Border between fundamental and bubble equilibria is complex (fractal)

The importance of memory

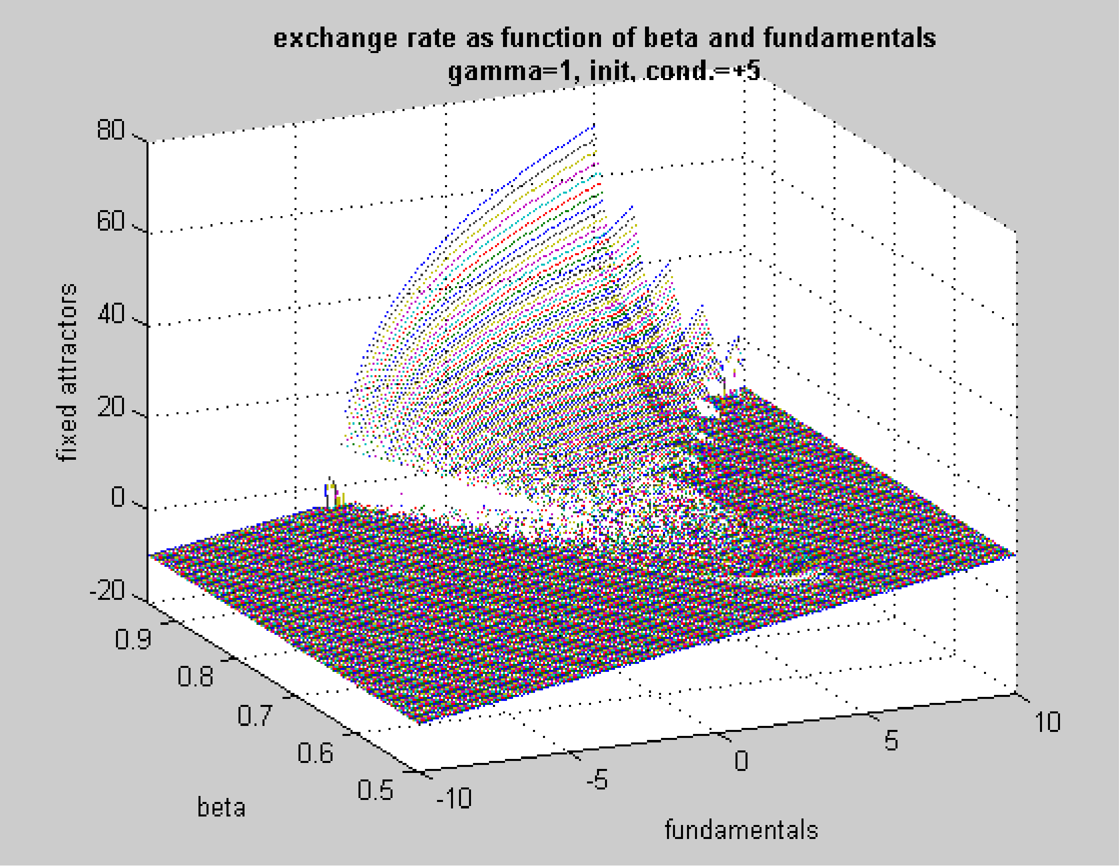


We introduce memory by allowing agents to remember the past using weights with exponential decay

When memory increases the space of fundamental equilibria increases

Why crashes occur

- It may not be clear yet why bubbles are always followed by crashes.
- Shocks in fundamental are key
- We performed following experiment
  - We fix the initial condition such that it produces a bubble equilibrium
  - We then compute the attractors for different shocks in fundamental



Suppose we are in a bubble equilibrium

Then a sufficiently positive(negative) shock in fundamental brings us back to the fundamental equilibrium (a crash)

Intuition: large displacement of fundamental strenghtens the hand of the fundamentalists

Thus shocks in fundamentals are sources of bubbles and subsequent crash

Basins of attraction around the fundamental steady state: sensitivity with respect to β

Basins of attraction

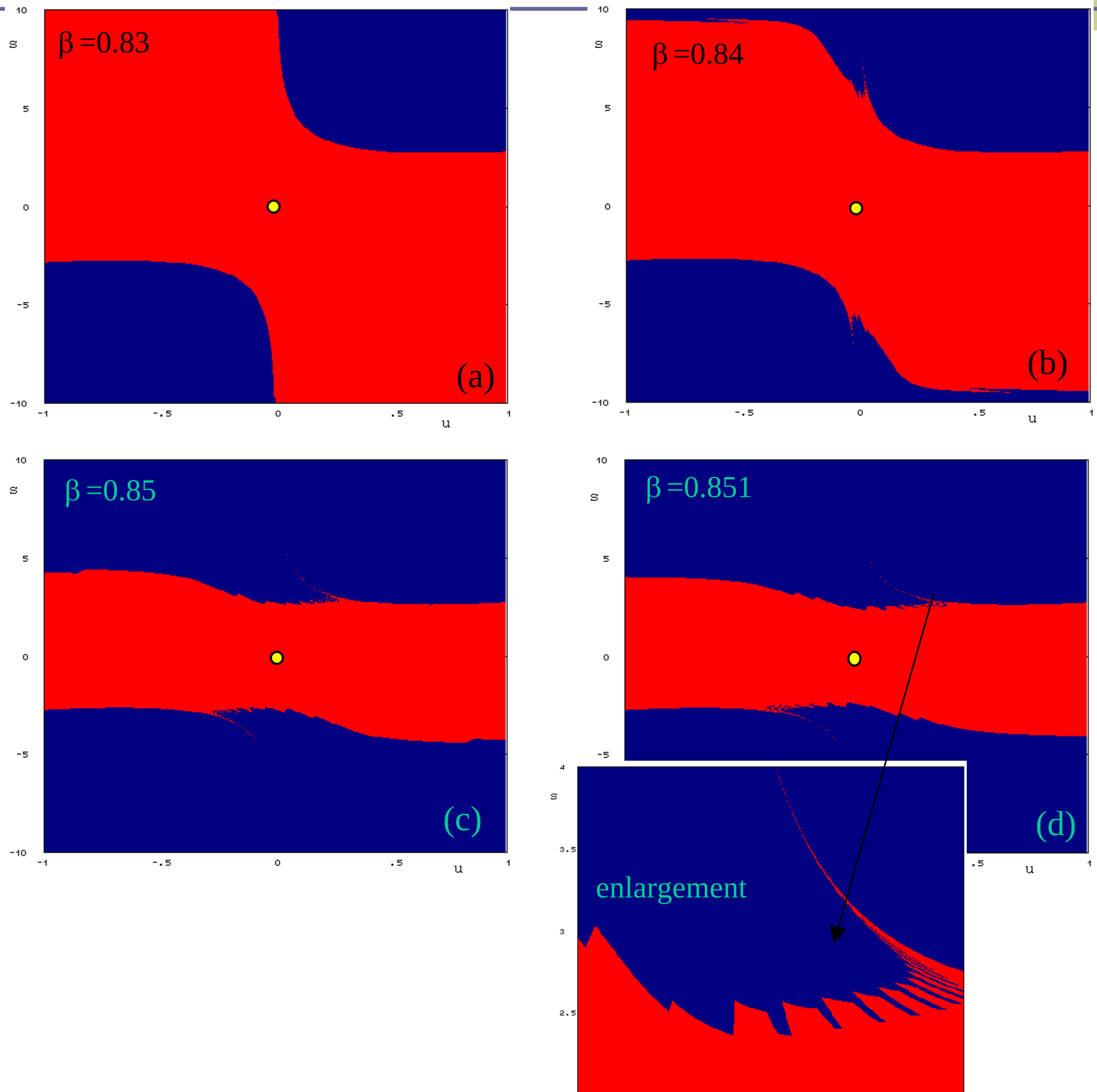
- fundamental
- bubble

initial condition

$y_0 = z_0 = 0 \quad \sigma^2_{f,0} = \sigma^2_{c,0} = 0.05 \quad u_0$ and s_0 varying

parameters

$\psi = 0.2 \quad \mu = 1 \quad \gamma = 1 \quad \theta = 0.6$



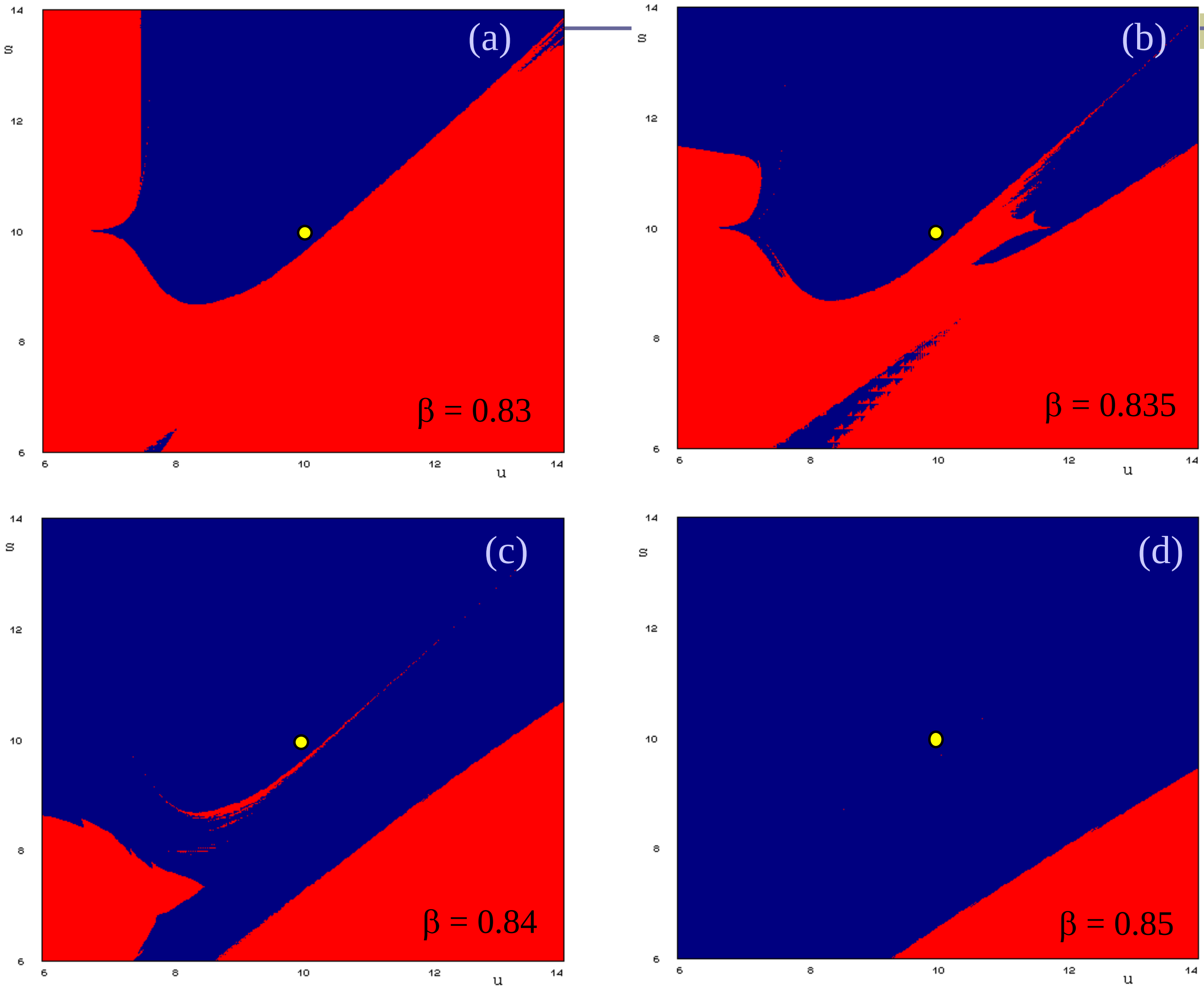
Basins of attraction around a “bubble equilibrium”: sensitivity with respect to β

parameters

$\psi = 0.2 \quad \gamma = 1 \quad \mu = 1 \quad \theta = 0.6$

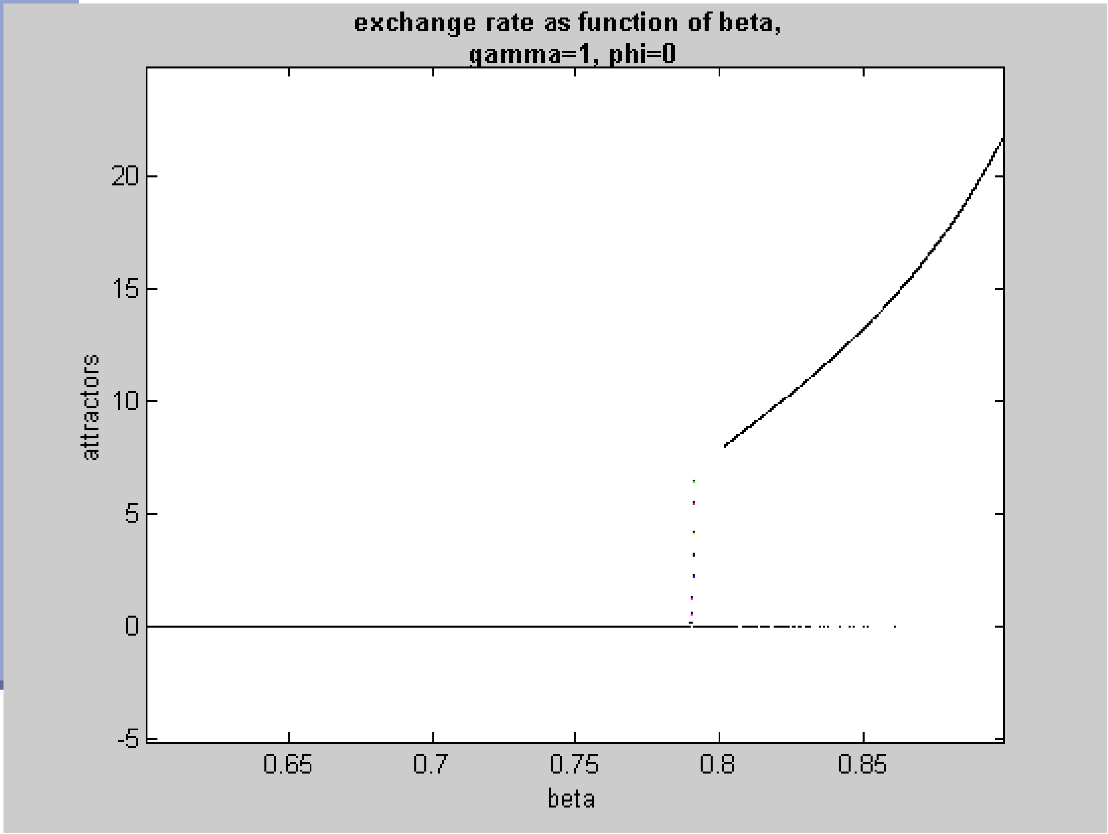
initial condition

$y_0 = z_0 = 10 \quad \sigma^2_{f,0} = 4 \quad \sigma^2_{c,0} = 0 \quad u_0$ and s_0 varying



Informational issues

- Agents use simple forecasting rules because they cannot comprehend the full complexity of the underlying model.
- The results of the model suggest that this is the right strategy to follow.
- For despite its simplicity, the model creates an informational environment that is too complex for an individual to understand and to process.
- To show this we analyse the complex boundary between fundamental and bubble equilibria



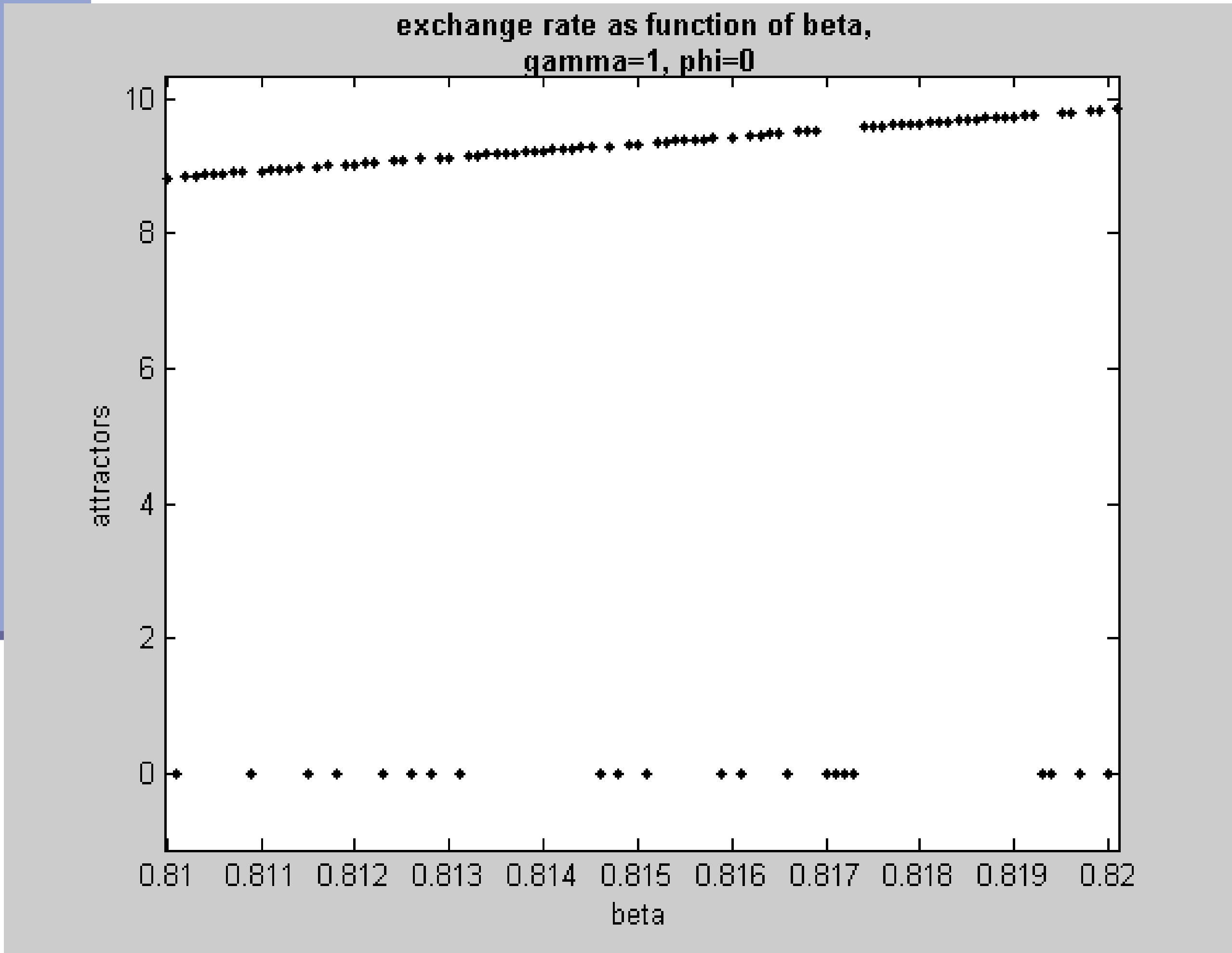
Suppose we know initial condition to be exactly +5

We take a slice from 3D figure in slide 24

Assume the forecaster has estimated beta to be 0.815 with standard error 0.005

Is this enough information to predict whether we move to fundamental or bubble equilibria?

Let's take a blow-up

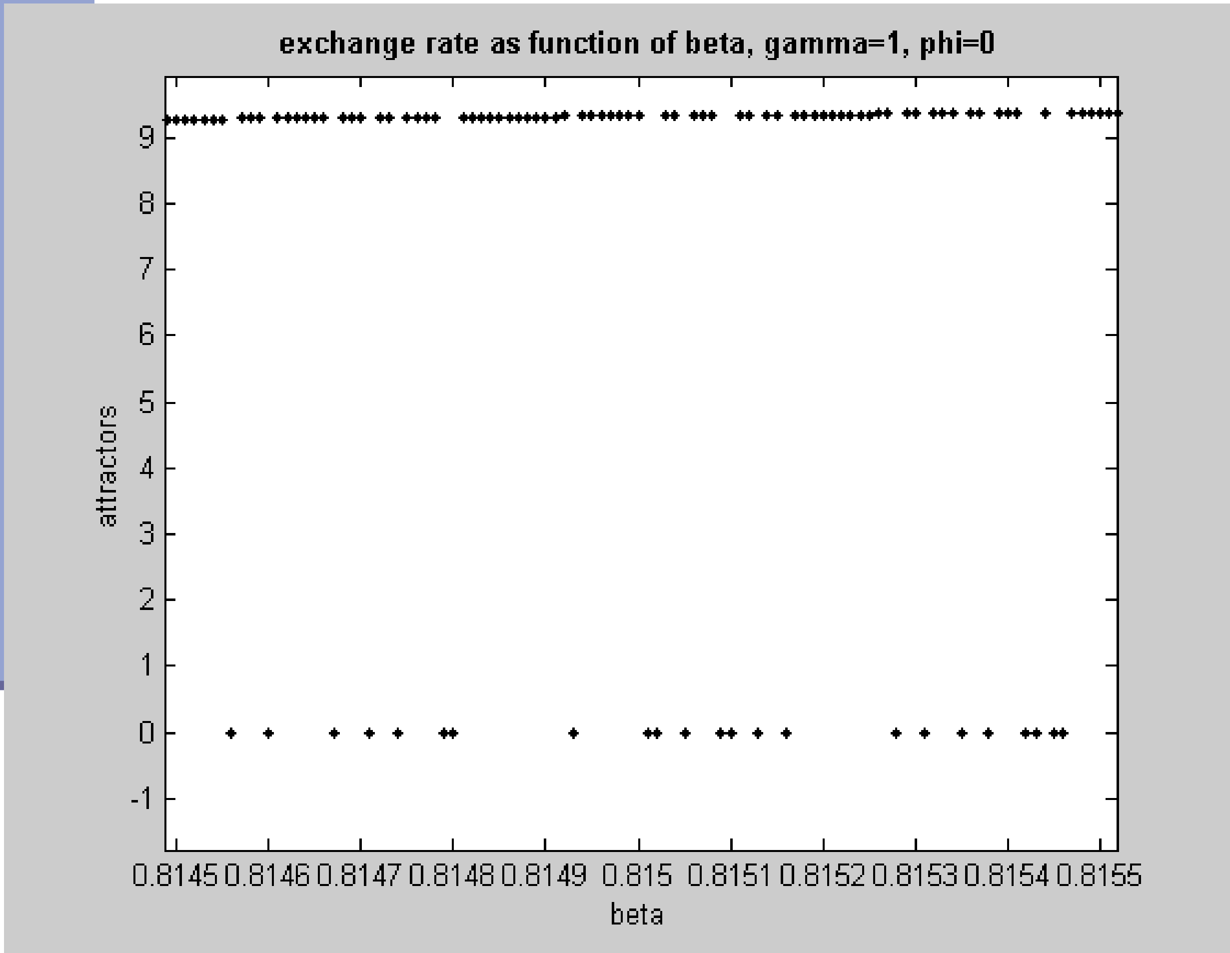


Our forecaster has 23% probability of a fundamental equilibrium, and 77% probability of a bubble equilibrium

Can he improve the precision of his forecast by better econometric techniques?

Suppose that he reduces standard error by factor of 10

We take a new blow-up by a factor of 10



Despite much greater precision of his estimate of beta his precision in forecasting a bubble has not increased at all

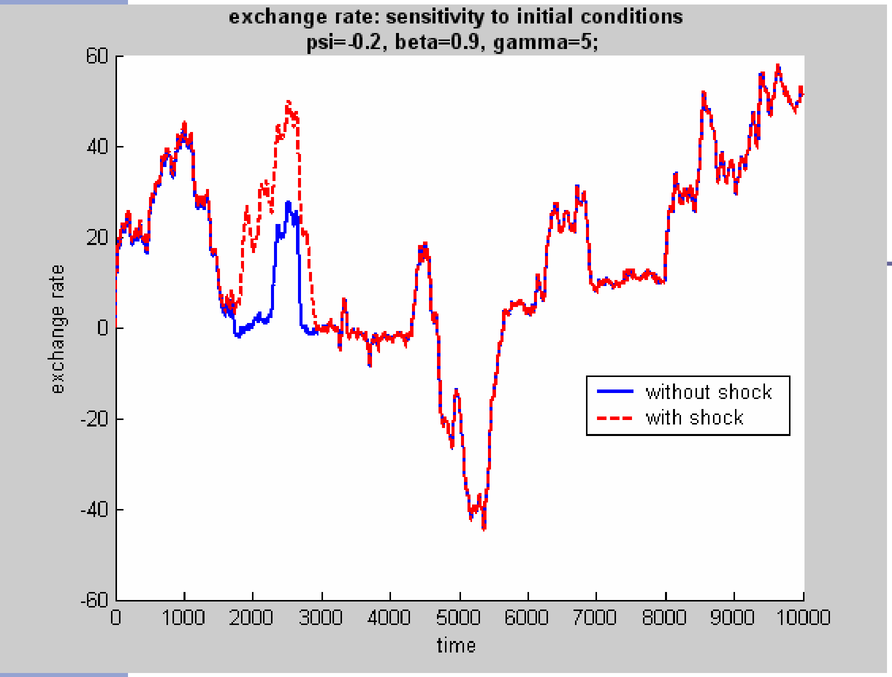
It does not pay to be a good econometrician

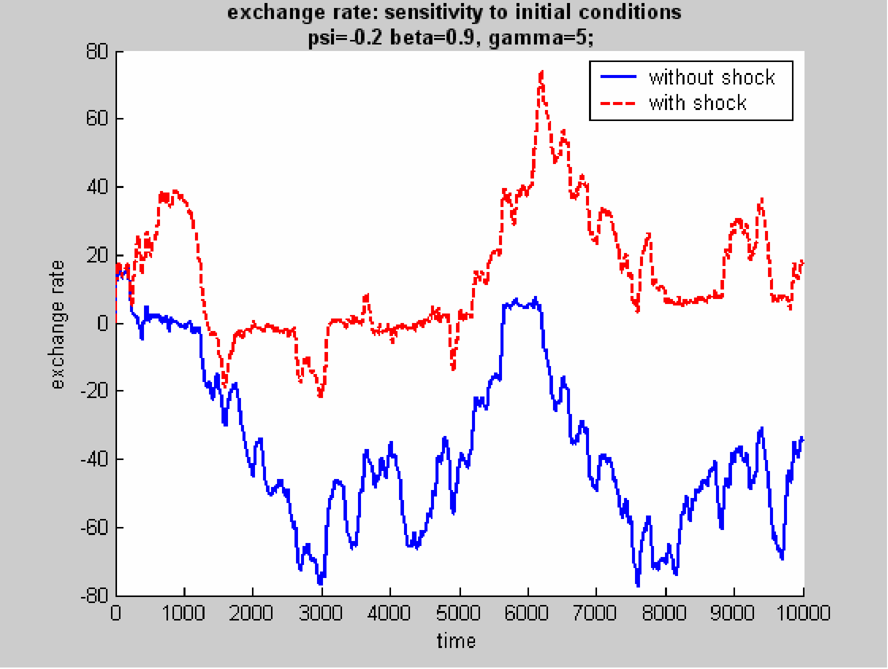
This result has to do with the fractal nature of the border between the bubble and fundamental equilibria

- Thus, even in a very simple model agents face enormous informational problems, that they cannot hope to solve.
- As a result, agents will not attempt to use all the information provided by the underlying structural model.

Sensitivity to initial conditions

- The fractal nature of the boundary between fundamental and non-fundamental equilibria produces a potential for sensitivity to initial conditions





We simulate the model twice with exactly the same realization of the fundamental variable

Only initial conditions differ slightly, i.e. +0.1

The exchange rate and the current account

- In the previous chapters we used a model in which fundamental and bubble equilibria co-exist. As a result, the exchange rate is disconnected from the fundamentals much of the time.
- These results were obtained in a model where the real sector of the economy is exogenous.
- This implies that the exchange rate does not affect the real sector.

- Thus there is no feedback of exchange rate changes into goods prices, output, export and import.
- In reality, however, it is likely that exchange rate movements affect real variables.
- In particular during a bubble the exchange rate becomes increasingly undervalued. This is likely to stimulate exports and discourage imports.

- Will these feedback mechanisms affect our basic results?
  - An increase in the exchange rate leads to more exports and less imports and thus to an improvement of the current account.
  - The latter means that the supply of foreign assets
  - to domestic wealth owners increases. But such an increase in the supply of the foreign asset must have some effect on its price.
  - In general, as we will see, such an increase in the supply of foreign assets will tend to reduce its price

- This mechanism implies that we have a potential mean reverting process in the exchange rate.
- i.e. when the exchange rate increases, say during a bubble, the ensuing increase in the supply of the foreign asset will tend to reduce the exchange rate again.
- Thus, even if there are no agents using fundamentalist forecasting rules anymore, there is still a mean reverting mechanism in the economy that can do its work of pushing back the exchange rate towards its fundamental value.

- How can we model the interaction between exchange rate movements and the supply of foreign assets?
- We postulate that there is a stable relationship between the equilibrium supply of the foreign asset and the fundamental exchange rate, i.e.

$$Z_t^* = \epsilon s_t^*$$

- there is a one to one relationship between the fundamental exchange rate and the equilibrium supply of foreign assets.
- The parameter ε will be called the "elasticity".

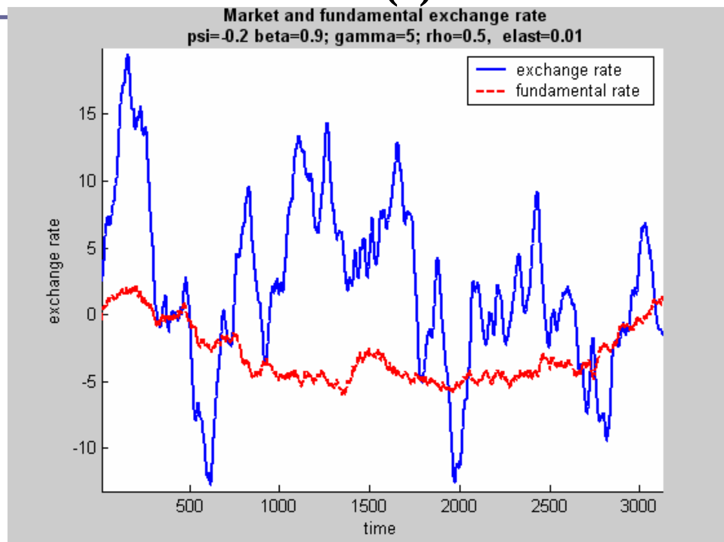
- the dynamics of the changes in the supply of foreign assets is described by the following equation:

$$Z_t - Z_t^* = \rho_z (Z_{t-1} - Z_{t-1}^*) + (1 - \rho_z)\epsilon(s_t - s_{t-1}^*)$$

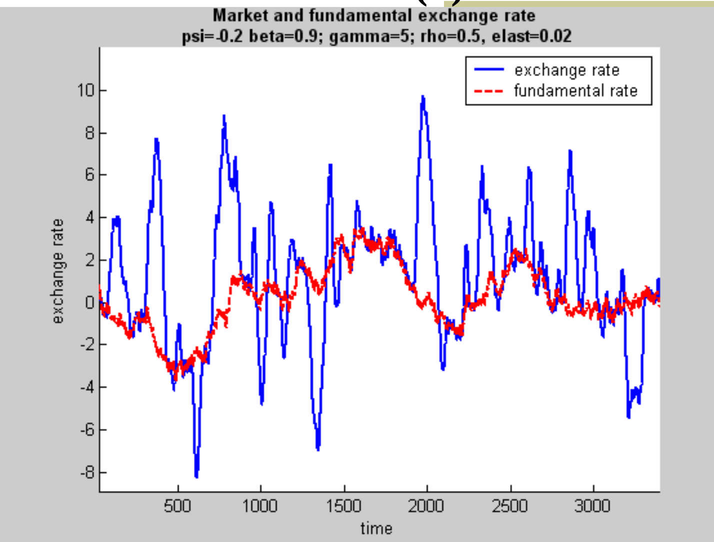
- ρ_z regulates the speed of adjustment of the supply of foreign assets

Stochastic simulation of the model

(a)



(b)



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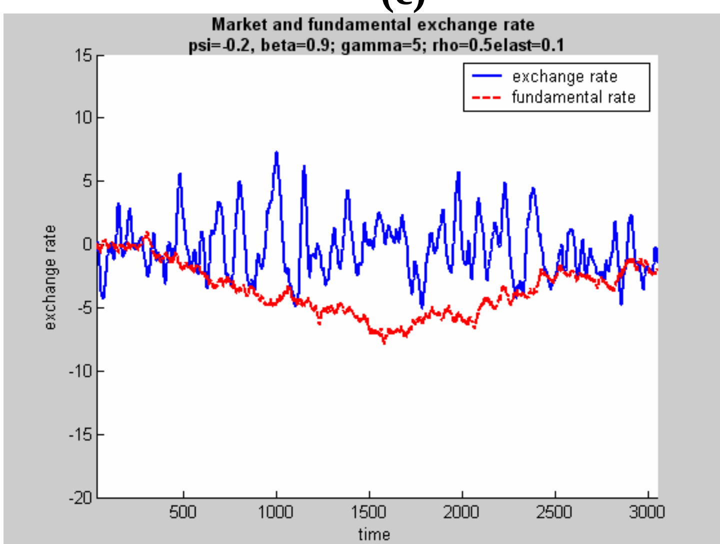

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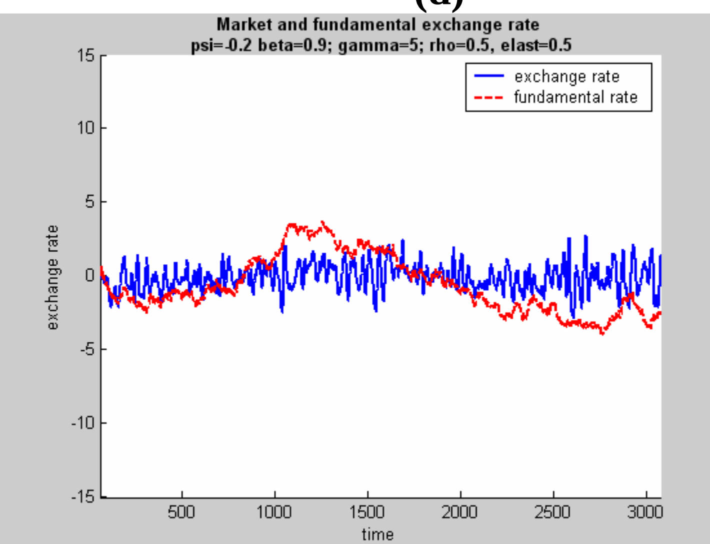
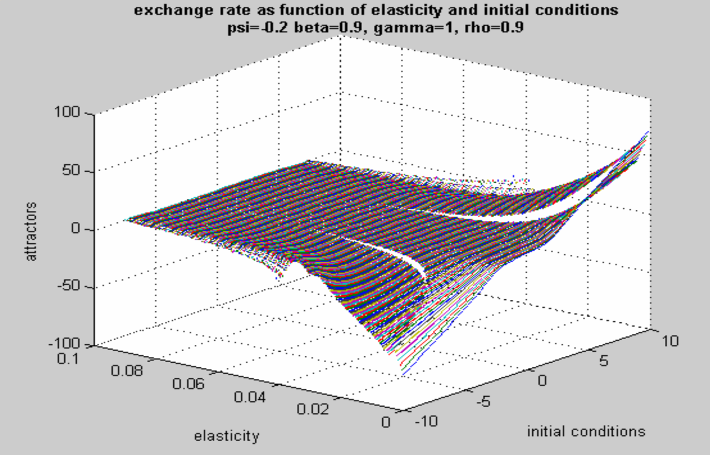
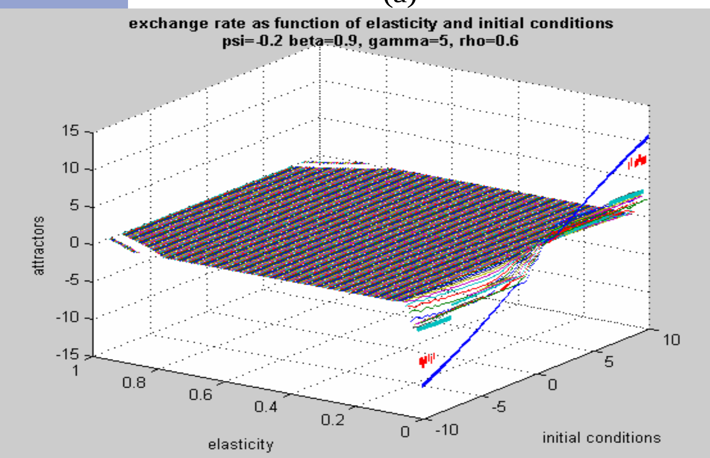


- Thus the strength of the asset supply mechanism has the effect of tying down the exchange rate to its fundamental value.
- At the same time this mechanism creates additional short-term volatility around the fundamental.

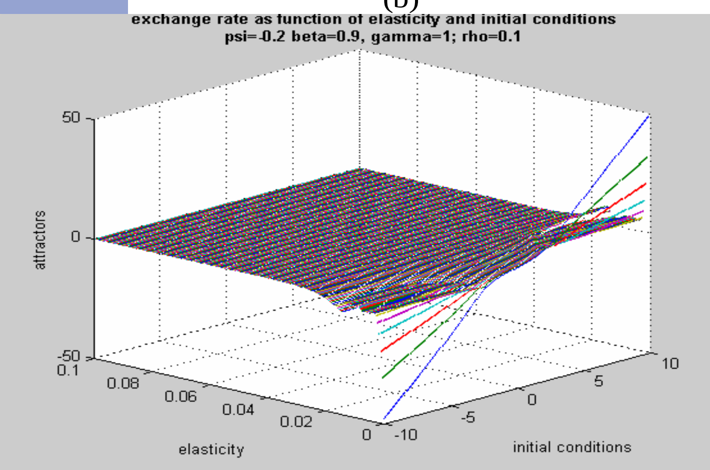
Deterministic analysis



(a)



(b)



Importance of the elasticity

As elasticity increases the zone of fundamental solutions increases.

Note also the importance of the speed of adjustment.

A high speed of adjustment (low ρ) has the effect of increasing the zone of fundamental equilibria.

Interpretation

- The stronger and the speedier the supply of foreign assets reacts to the exchange rate the less likely it is that bubble equilibria occur.
- This is not really surprising.
- The asset supply mechanism that we modeled introduces a mean reversion process.
  - If this mean reversion process is strong enough it strengthens the hands of the fundamentalists who use a mean-reverting forecasting rule.
  - As a result, the probability that chartist rules will tend to dominate and generate bubbles is reduced.

Conclusion

- Exchange rate movements affect the current account.
- The latter in turn changes the net supply of foreign assets and feeds back on the exchange rate.
- The effect of making the supply of net foreign assets endogenous is that it can eliminate bubble equilibria.
- This will happen if the exchange rate changes have a sufficiently large and fast effect on the current account.
- In that case we also found that the profitability of fundamentalist rules is strongly increased, thereby also increasing the popularity of these rules in forecasting the exchange rate.

- What is the empirical evidence of the sensitivity of the current account?
- The consensus today is that this sensitivity is rather weak. (see Krugman (1987), Frankel and Rose(1994), Obstfeld and Rogoff(2000)).
- In the short run, i.e. over periods extending to several quarters, there is very little evidence that the exchange rate affects the current account.
- This has a lot to do with the fact that firms tend to "price to market",
- As a result of this pricing to market, trade flows do not react much to (short-term) exchange rate movements. Trade flows appear to be disconnected from short-term exchange rate movements.

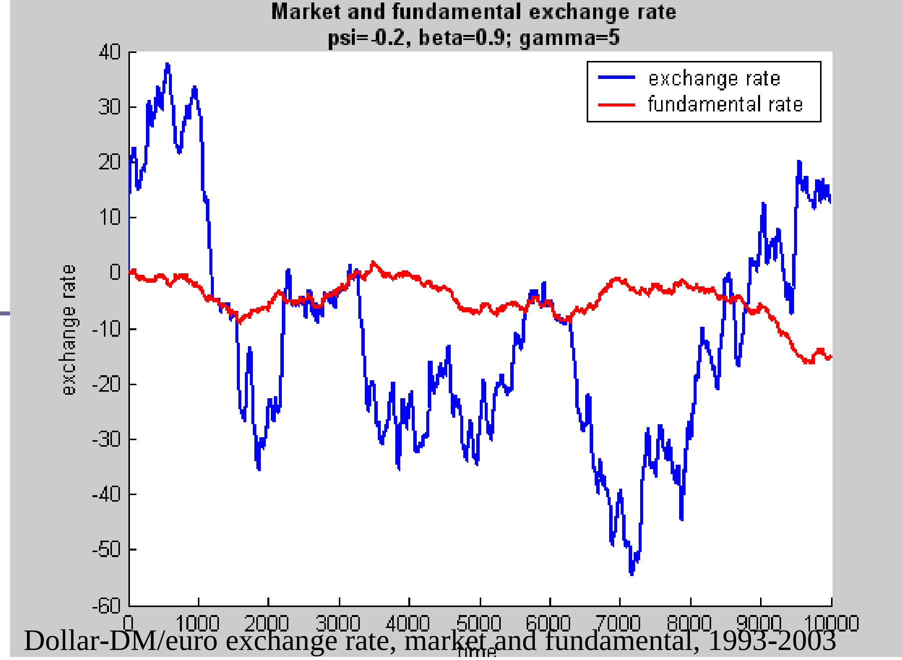
- Thus, the disconnect puzzle has two dimensions.
  - It relates to the fact that trade flows are not very responsive to exchange rate changes,
  - and it also means that the exchange rate is disconnected from its underlying fundamental.
- The existence of a disconnect phenomenon whereby the current account is only weakly sensitive to the exchange rate implies that the feedback mechanism is a weak force so that it will most often not prevent bubbles and crashes in the exchange rate from emerging.

Empirical relevance of model

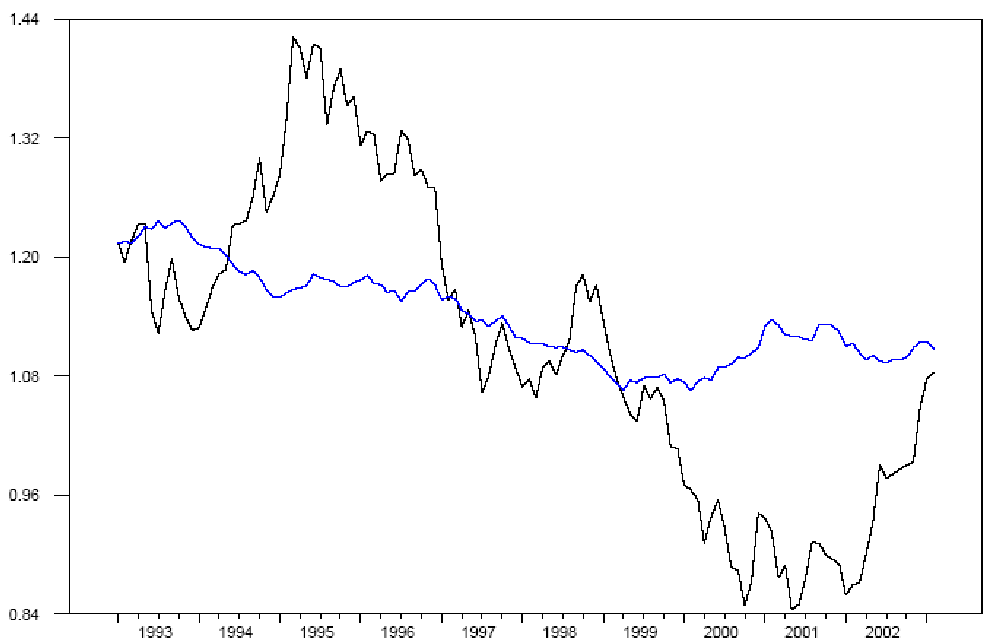
- We calibrate the model in such a way as to mimick main empirical regularities
  - Disconnect puzzle
  - Excess volatility
  - Fat tails and excess kurtosis
  - Volatility clustering (GARCH)

Disconnect puzzle

- The major puzzle in exchange rate economics
- Our model mimicks this puzzle



Dollar-DM/euro exchange rate, market and fundamental, 1993-2003



Source: Ehrmann, M., and Fratzscher, M., Exchange Rates and Fundamentals: New Evidence from Real-time Data, forthcoming in Journal of International Money and Finance, 2004

Error correction model of simulated exchange rate and fundamental

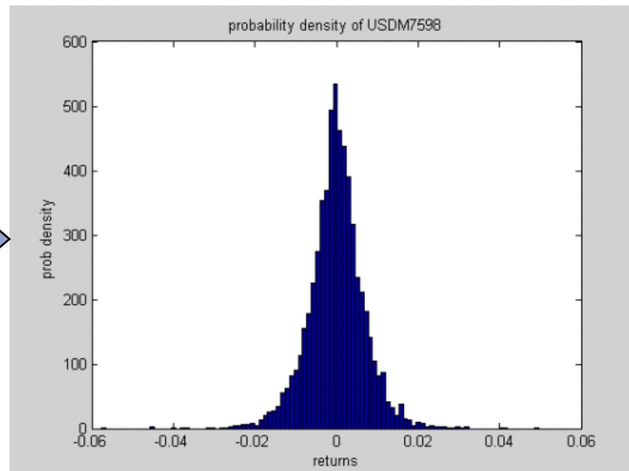
We specify an error correction model on the simulated exchange rate and fundamental. We replicate an empirical finding that:

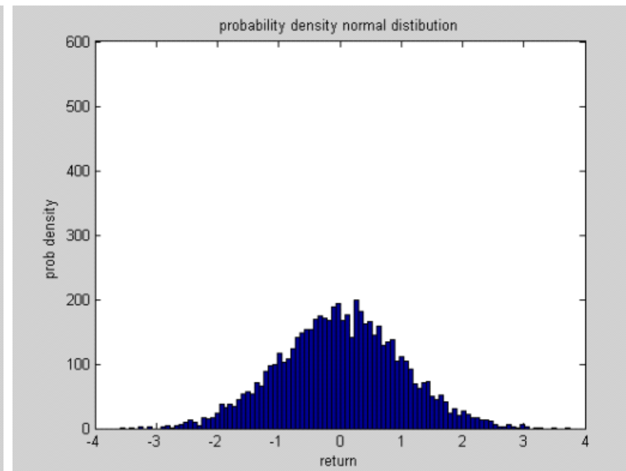
- There is a long run cointegration relationship between the exchange rate and the fundamental
- the speed of adjustment of both the exchange rate towards this long run equilibrium relationship is very weak
- Thus, there is a disconnect puzzle

Returns have fat tails and excess kurtosis

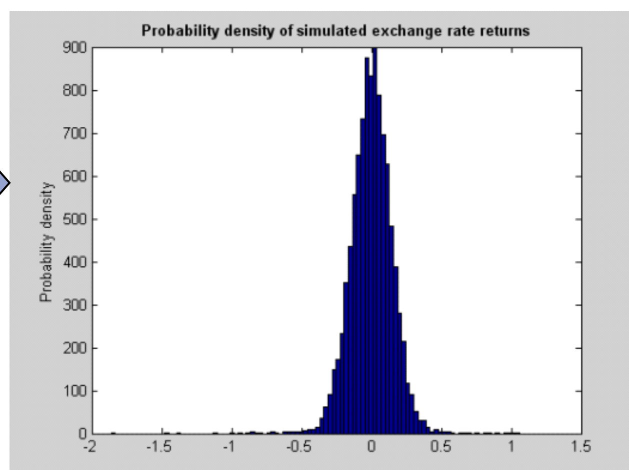
Normal distribution

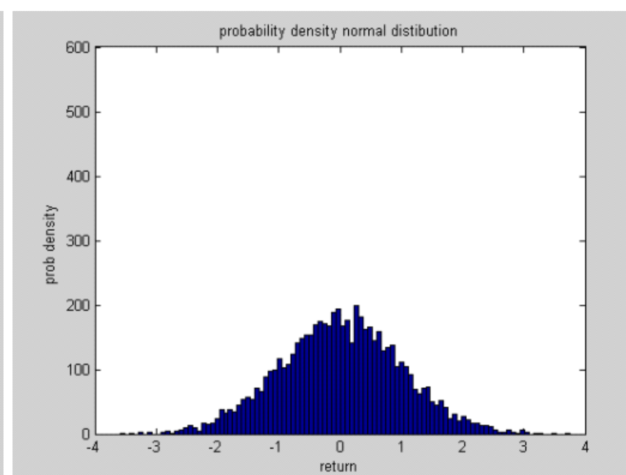
Real life distribution of returns



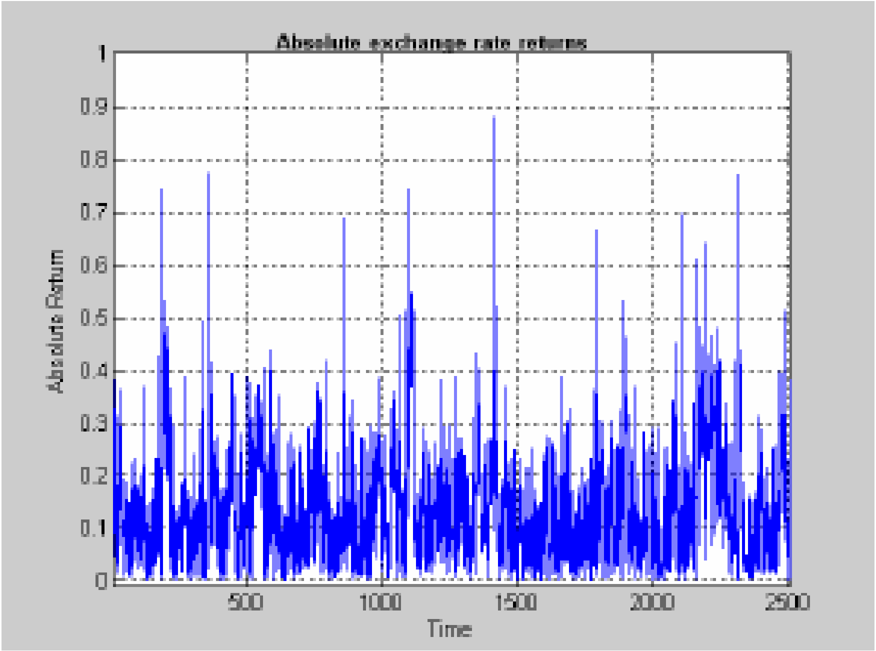


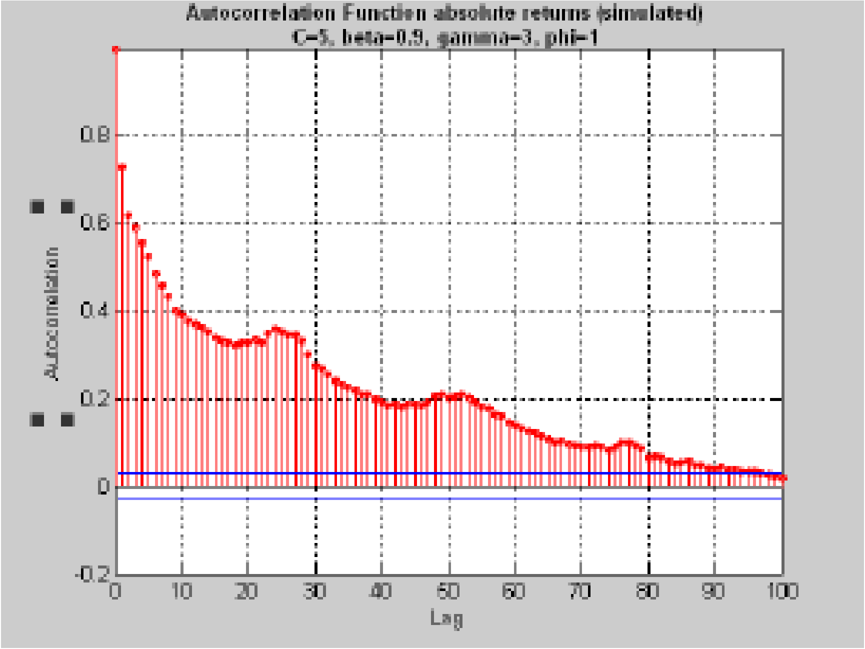
Simulated distribution of returns





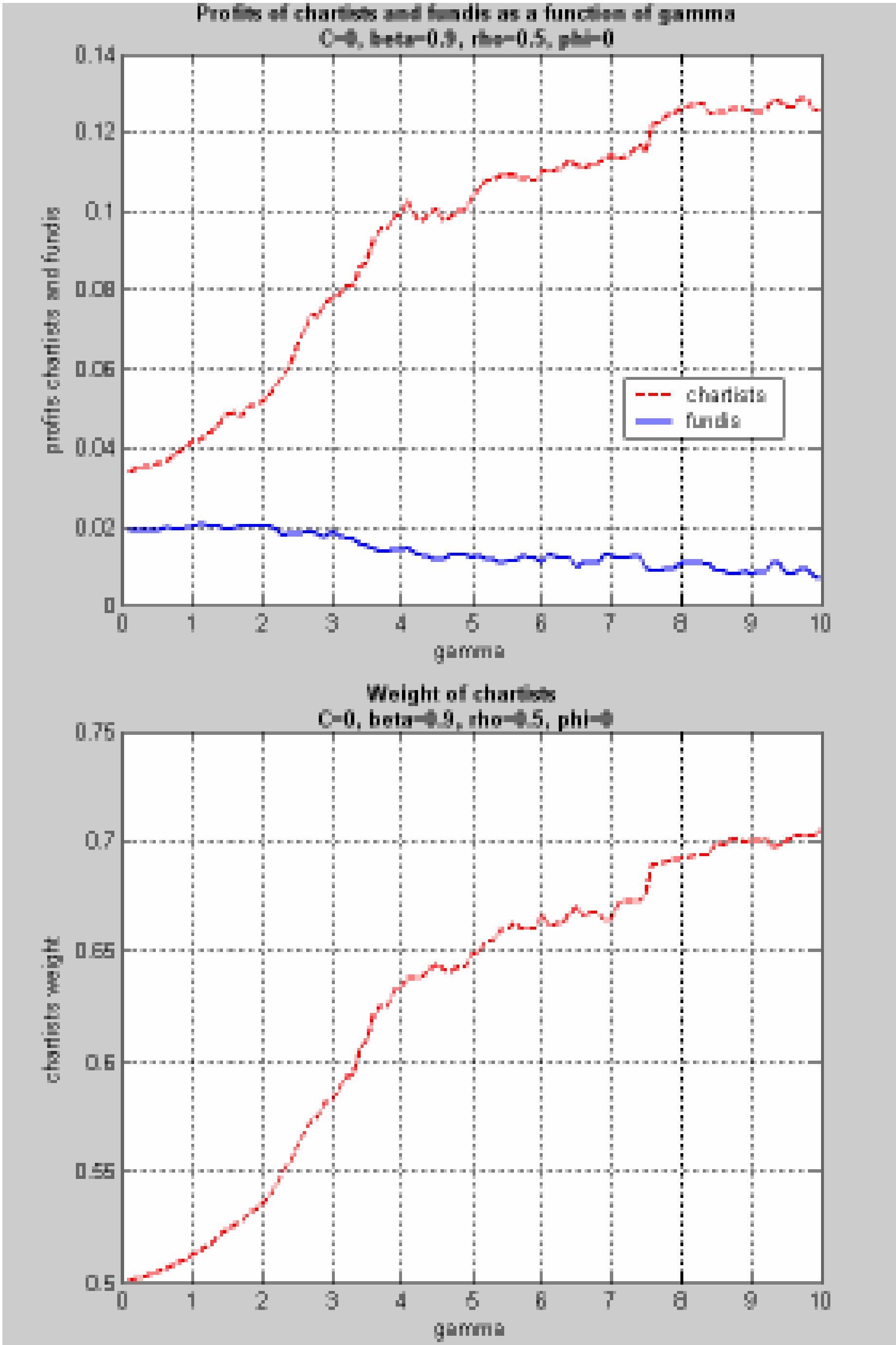
- Our model also mimicks other empirical puzzles of the foreign exchange markets
- Volatility clustering


Absolute exchange rate returns
Absolute Return
Time
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
500
1000
1500
2000
2500


Autocorrelation Function absolute returns (simulated)
C=5, beta=0.9, gamma=3, phi=1
Autocorrelation
Lag
-0.2
0
0.2
0.4
0.6
0.8
0
10
20
30
40
50
60
70
80
90
100

Is chartism evolutionary stable?

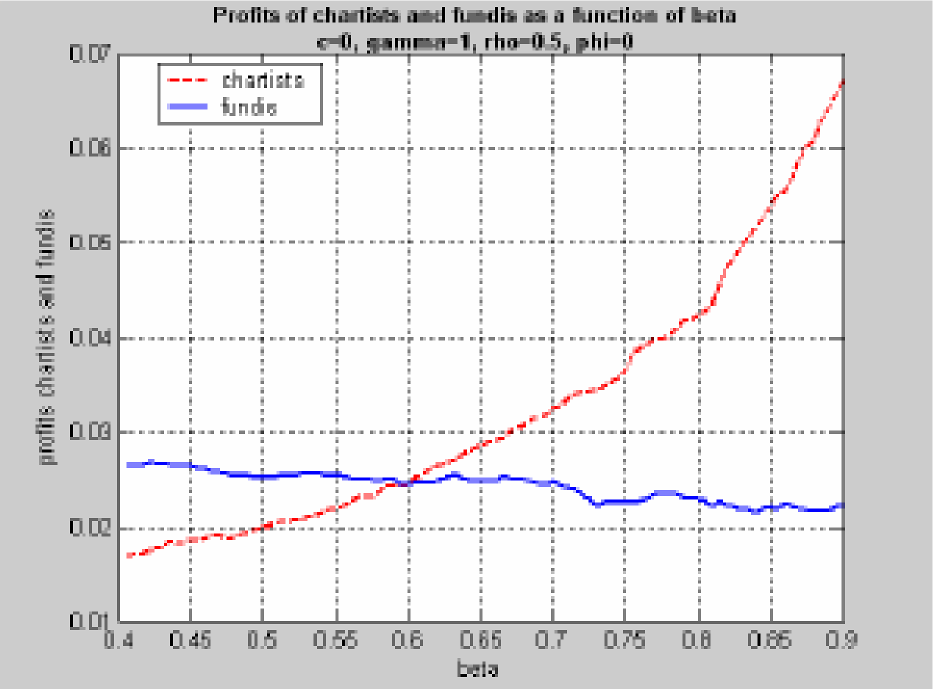
- Traditional analysis is scornful about chartism and technical analysis
- In the REEM model there is no place for these rules.
- Reality is that technical analysis is widely used, in fact more so than fundamental analysis
- Can our model replicate this empirical observation?

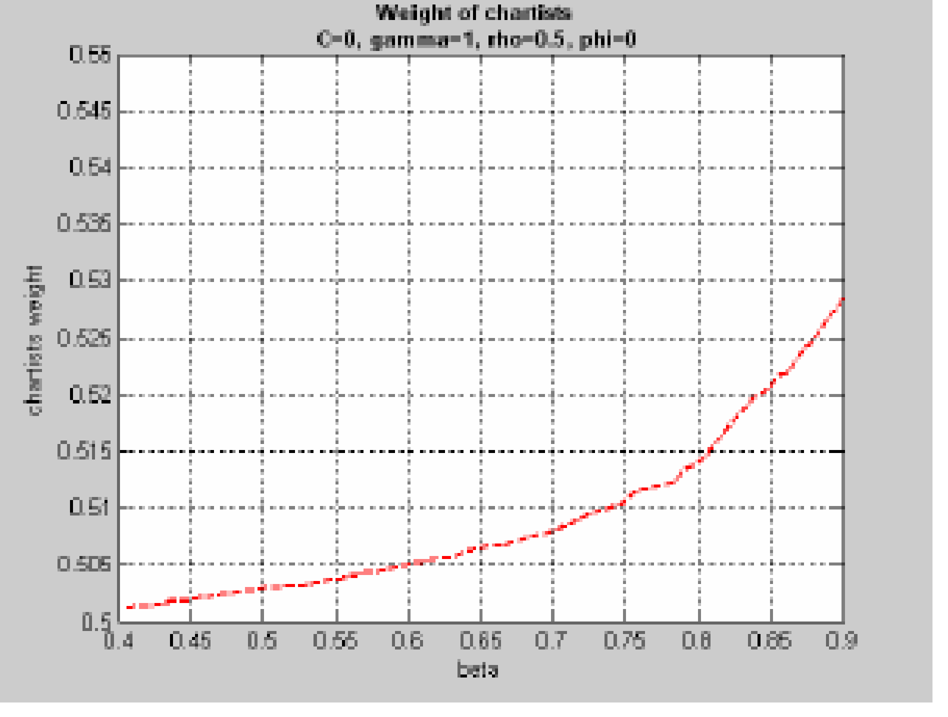


We compute the profitability of chartist and fundamentalist rules

Profitability of chartist rules increases with gamma

Weight of chartists increases with gamma

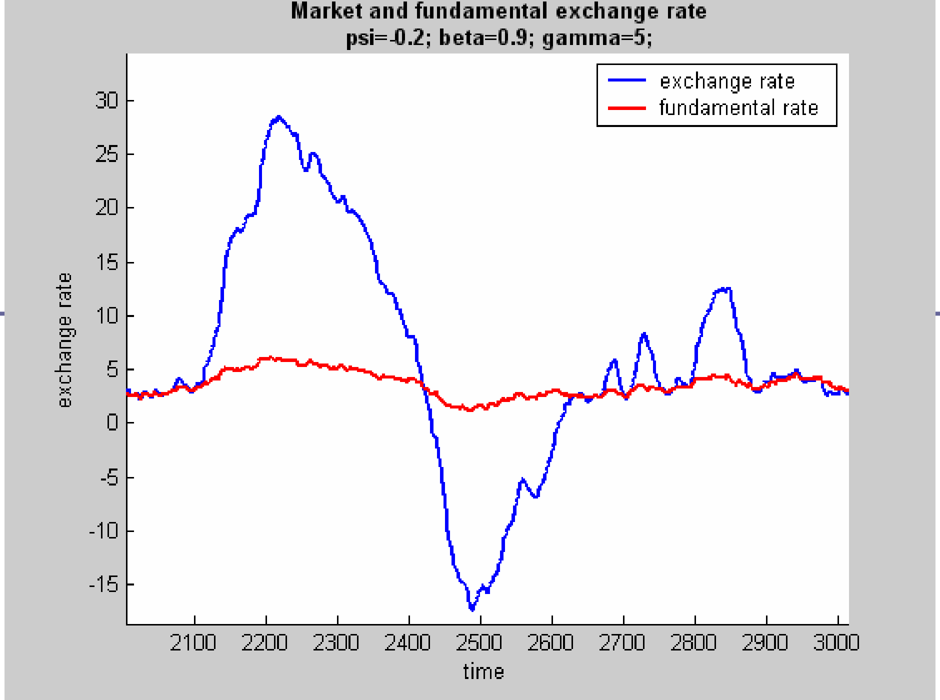

Profits of chartists and fundis as a function of beta
c=0, gamma=1, rho=0.5, phi=0
chartists
fundis
profits chartists and fundis
beta
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9


Weight of chartists
C=0, gamma=1, rho=0.5, phi=0
chartists weight
beta
0.55
0.545
0.54
0.535
0.53
0.525
0.52
0.515
0.51
0.505
0.5
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
0.85
0.9

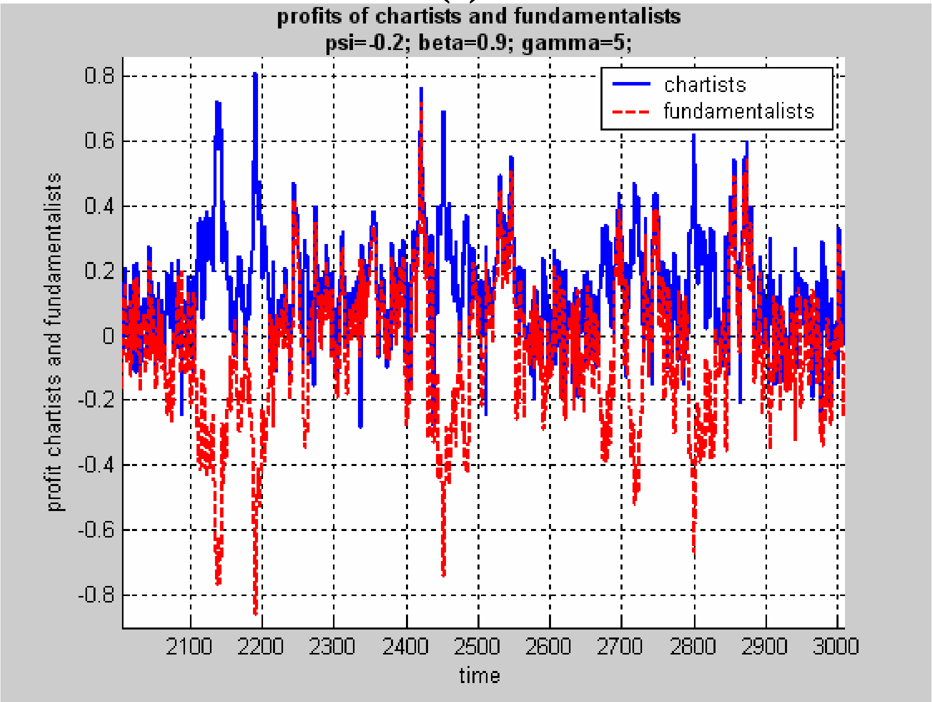
Some results are noteworthy.

- Chartist forecasting rules turn out to be more profitable than fundamentalist rules for most parameter values, leading to systematically larger share of chartism compared to fundamentalism.
- Second when γ and β increase the profitability of chartist rules increases relative to the profitability of fundamentalist rules.

- This result is related to the fact that as these parameters increase, the probability of the occurrence of bubbles increases.
- Chartist forecasting rules become more profitable in an environment of turbulence during which the exchange rate deviates from its fundamental.



(a)



During bubbles chartists make dramatically more profits

Fundamentalists make major losses; that's why they drop out of the market during bubbles

- Fundamentalist rules appear to be loss making on average.
- Does this mean that instead of chartists, the fundamentalists are in danger of extinction?
- We measure the profitability of forecasting **rules**.
- During the bubble phases the use of chartist rules is very profitable while the use of fundamentalist rules is loss making.
- As a result, most agents switch to the use of chartist rules and few if any agents continue to use fundamentalist rules during these bubble phases.

Conclusion

- The world we have modelled is one in which agents do not understand its complexity
- Therefore they use simple rules of behaviour
- which they check ex post (fitness criterion)
- This is the way to introduce discipline into the model
- In such a world we get a very different dynamics compared to rational expectations world

Conclusion

- Nature of the dynamics
  - There are bubble equilibria that attract the asset prices
  - They will be reached as a result of shocks which makes extrapolating forecasting profitable
  - Sensitivity to initial conditions, or the importance of trivial events

- Once in a bubble equilibrium one can stay there for a long time … or for a very short time
- As a result, asset price is disconnected from fundamentals very often.
- The switch from one regime to the other creates turbulence

Policy implications

- In the world we have modeled, policies can have powerful effects
- Interventions in the market can move the asset price, and push it towards a new equilibrium
- Thus, potentially effect of policy is strong