Macroeconomic and Stock Market Interactions with Endogenous Aggregate Sentiment Dynamics

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Introduction

- Understanding the interplay between financial markets and the macroeconomy has become a central issue in macroeconomics, especially after the 2007 Global Financial Crisis.
- While mainstream macroeconomics still relies on the rational expectations paradigm, the behavioral finance literature has focused on heterogenous and boundedly rational beliefs, see e.g. Beja & Goldman (1981), Day & Huang (1990), Chiarella (1992), Lux (1995) and Brock & Hommes (1997,1998).
- Recently, heterogenous beliefs have been incorporated into macroeconomic models, see e.g. Branch & McGough (2010), Branch & Evans (2011), De Grauwe (2011, 2012) and Proaño (2011, 2013).

The Brock Hommes (1997) Approach

- Agents are boundedly rational and learn from their past mistakes.
- Agents can choose between different types of forecasting rules (two for the sake of simplicity: chartism and fundamentalism).
- Sophisticated rules may come at information gathering costs (Simon, 1957), simple rules are freely available.
- Agents evaluate the net past performance of all rules, and tend to follow rules that have performed better in the recent past.
- Evolutionary fitness measure $\equiv$ past realized net profits.

Evolutionary fitness measure

- **Evolutionary fitness measure:** most successful strategies attract more followers.
- The fitness function or performance measure is the weighted average of **past realized net profits**

$$U_{ht} = \pi_{ht} + wU_{h,t-1}$$

- π_{ht} net realized profit (minus costs) strategy h.
- w measures **memory strength**
  - $w = 1$: infinite memory; fitness $\equiv$ accumulated profits.
  - $w = 0$: memory one lag; fitness $\equiv$ most recently realized net profits.

Discrete choice model

- **Fractions of beliefs** are updated in each period (discrete choice model), according to:

$$n_{ht} = \frac{e^{\beta U_{h,t-1}}}{Z_{t-1}}$$

where $Z_{t-1} = \sum e^{\beta U_{h,t-1}}$ is a normalization factor. and β is the **intensity of choice**

- $\beta = 0$: all types equal weight (random choice).
- $\beta = \infty$: "neoclassical limit", i.e. all agents choose best predictor.

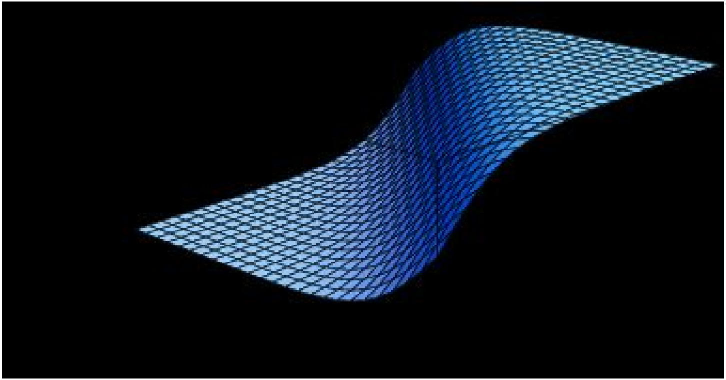


Figure: Source: Proaño (2013)

The (Haken-)Weidlich-Haag-Lux Approach

- By contrast, only a few studies such as Franke (2012), Chiarella, Di Guilmi and Zhi (2015) and Flaschel, Hartmann, Malikane and Proaño (2015) have developed macroeconomic models using the Weidlich-Haag-Lux (WHL) approach.
- While the core of the BH approach is more "microfounded", the WHL approach allows for a more "macrofounded" perspective, as the switch is determined by an aggregate sentiment index composed e.g. by macroeconomic variables.
- Exception: Proaño and Lojak (2020, 2021).

The WHL approach incorporates an additional link from the macroeconomic environment to microeconomic decision-making based on Keynes' notion that

> *"Knowing that our own individual judgment is worthless, we endeavor to fall back on the judgment of the rest of the world which is perhaps better informed. That is, we endeavor to conform with the behavior of the majority or the average. The psychology of a society of individuals each of whom is endeavoring to copy the others leads to what we may strictly term a* conventional *judgment."*
> *Keynes (1937, p. 114).*

This Paper

- studies the interplay between aggregate sentiments in stock markets and the real economy using the WHL approach to model the expectations formation process in stock markets
- examine whether an aggregate sentiment-driven macrofinancial environment can be intrinsically stable or whether stabilization properties are necessary to guarantee macroeconomic stability.

Results Overview

1. Real-Financial Interactions (without opinion dynamics).
   - Stability depends on sensitivity of output to Tobin's q (stock prices)
2. Opinion Dynamics
   - One or three equilibria
   - Equilibrium with equal populations always exists but is unstable.
3. Real/ Financial Interactions with Opinion Dynamics.
   - Multiple equilibria.
   - At stable R-F equilibrium- Opinion dynamics increase volatility.
   - At unstable R-F equilibrium- Opinion dynamics prevent the path from being explosive.

Core Real-Financial Interactions

Builds on Blanchard (1981), Turnovsky (1995) and Chiarella/Flaschel (2000)

- The law of motion of output Y is given by:

$$\dot{Y} = \beta_y(Y^d - Y) \tag{1}$$

  where β_y is the speed of adjustment concerning the goods-market disequilibria.

- Aggregate demand is given by

$$Y^d = a_y Y + A + a_q(p_e - p_{eo})E \tag{2}$$

  where p_e is the equity price, and the Brainard and Tobin (1968) q is given by

$$q = p_e E / pK$$

Real-Financial Interactions (continued)

Builds on Asada et al (2011)

- The expected return on equity ρ_e^e is

$$\rho_e^e = \frac{bY}{p_e E} + \pi_e^e \tag{3}$$

  where b is profit share, $\frac{bY}{p_e E}$ is the dividend rate; π_e^e is the expectation on capital gains.

- The rate of growth of prices $\hat{p}_e$ is

$$\hat{p}_e = \beta_e(\rho_e^e - \rho_{eo}^e) = \beta_e \left(\frac{bY}{p_e E} + \pi_e^e - \rho_{eo}^e \right) \tag{4}$$

  where ρ_{eo}^e is the return on equity when the expectation of capital gains is zero (steady state value).

Fundamentalists and Chartists

- A total of $2N = N_c + N_f$ agents populated the economy
- N_c agents are *chartists* who adopt a simple adaptive mechanism to forecast the evolution of capital gains
- N_f *fundamentalists* who expect capital gains to converge back to the long run value
  - Let $x = \frac{N_c - N_f}{2N}$ be the relative weight of chartists:
  - if $x = 1$ then everyone is a chartist
  - if $x = -1$ then everyone is a fundamentalist
- $\nu_c = \frac{N_c}{2N} = \frac{1+x}{2}$: fraction of *chartists* in the economy
- $\nu_f = \frac{N_f}{2N} = 1 - \nu_c$: fraction of *fundamentalists* in the economy

Opinion Dynamics

Builds on Weidlich and Haag (1983), Lux (1995, 1998) and Franke (2012)

Evolution of x is given by

$$\dot{x} = (1-x)p(s)^{f\to c} - (1+x)p(s)^{c\to f} \tag{5}$$

where the transition probabilities be

- $p(s)^{f\to c} = \beta_x \exp(as)$
- $p(s)^{c\to f} = \beta_x \exp(-as)$

with the opinion switching index s assumed to be given by:

$$s = s_x x + s_y(Y - Y_0) - s_{p_e}(p_e - p_{eo})^2 - s_{\pi_e^e}(\pi_e^e)^2 \tag{6}$$

Aggregate Expectations

The law of motion of the *aggregate* expectations on capital gains π_e^e is assumed to be given by

$$\begin{aligned}
\dot{\pi}_e^e &= \nu_c \overbrace{\beta_{\pi_e^{e,c}}(\hat{p}_e - \pi_e^e)}^{\text{chartists}} + (1-\nu_c) \overbrace{\beta_{\pi_e^{e,f}}(0 - \pi_e^e)}^{\text{fundamentalists}} \\
&= \nu_c \beta_{\pi_e^{e,c}} \hat{p}_e - (\nu_c \beta_{\pi_e^{e,c}} + (1-\nu_c)\beta_{\pi_e^{e,f}})\pi_e^e \\
&= \beta_{\pi_e^e}[\nu_c \hat{p}_e - \pi_e^e], \qquad (7)
\end{aligned}$$

with $\hat{p}_e$ given by equation (4) and $\beta_{\pi_e^{e,c}} = \beta_{\pi_e^{e,f}} = \beta_{\pi_e^e}$ for simplicity.

Model Equations

The complete model reads as follows:

$$
\begin{aligned}
\dot{Y} &= \beta_y[(a_y - 1)Y + a_q(p_e - p_{eo})E + A], && (8)\\
\dot{p}_e &= \beta_e \left(\frac{bY}{p_e E} + \pi_e^e - \rho_{eo}^e\right) p_e, && (9)\\
\dot{\pi}_e^e &= \beta_{\pi_e^e} \left(\frac{1+x}{2}\beta_e \left(\frac{bY}{p_e E} + \pi_e^e - \rho_{eo}^e\right) - \pi_e^e\right), && (10)\\
\dot{x} &= (1-x)\beta_x \exp(a_x s) - (1+x)\beta_x \exp(-a_x s). && (11)
\end{aligned}
$$

Main Results

Core Real Financial Interactions

The dynamical system formed by the equations for $\dot{Y}$ and $\dot{p}_e$ (8) and (9), respectively, has a unique steady state:

$$Y_o = \frac{A}{1-a_y} \qquad \text{and } p_{eo} = \frac{bA}{(1-a_y)\rho^e_{eo}E}$$

with the following stability conditions:

(i) if $\dfrac{a_q b}{1-a_y} < \rho^e_{eo}$, then the steady state is (asymptotically) stable;

(ii) if $\dfrac{a_q b}{1-a_y} > \rho^e_{eo}$, then the steady state is an (unstable) saddle point.

Real Financial Interactions with Endogenous Capital Gains Expectations

Consider the dynamical system formed by equations for $\dot{Y}$, $\dot{p}_e$ and π_e^e, (8), (9) and (10), respectively, and let $\beta_e < 1$. For any $\nu_c \in [0, 1]$, a unique steady state exists, where

(i) if $a_q b/(1 - a_y) < \rho_{eo}^e$ then the steady state is locally (asymptotically) stable,

(ii) if $a_q b/(1 - a_y) > \rho_{eo}^e$ then the steady state is unstable.

Capital Gains Expectations and Opinion Dynamics

Consider the dynamical system formed by equations for $\dot{Y}$, $\dot{p}_e$, π_e^e, and $\dot{x}$ (8), (9), (10) and (11), respectively, and let $\beta_e < 1$.
If the influence of herding on the switching index is high ($s_x > 1/a_x$), then there exist three steady state values of x_0 where:

(i) populations are equal,

(ii) fundamentalists dominate and

(iii) chartists dominate. The first steady state is unstable, while the others are stable.

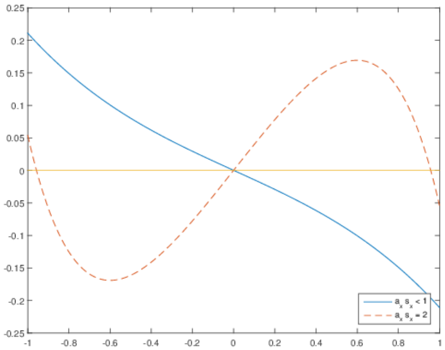
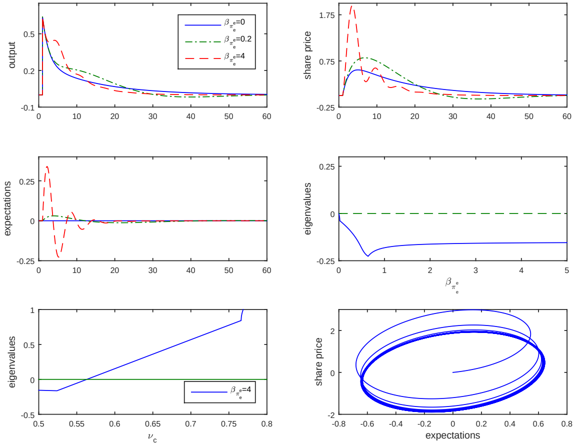


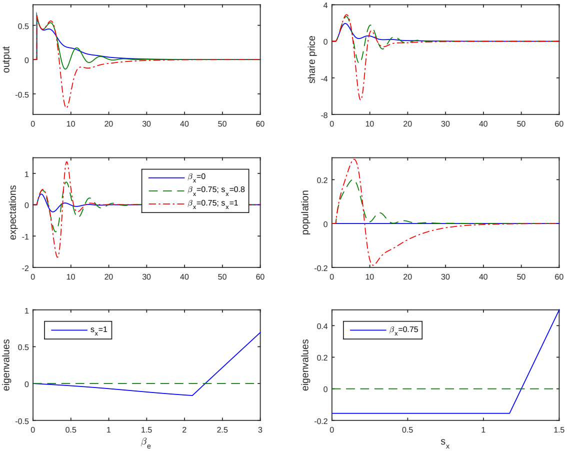
Figure: Steady states of population dynamics for different values of a_x and s_x

Numerical Simulations



- Endogenous capital gains expectations create oscillating dynamics
- $\beta_{\pi_e^e} \uparrow \rightarrow$ Output returns faster to steady state
- larger stock price volatility

Figure: Dynamic responses following a positive one-percent output shock for the 2D model (Y, p_e) and 3D model (Y, p_e, π_e^e) and maximum eigenvalues for the 3D model (Y, p_e, π_e^e) with $s_x < 1/a_x$.



- $x \uparrow \rightarrow \pi_e^e \uparrow \rho_e^e \uparrow \rightarrow p_e \uparrow$
- $p_e \uparrow \rightarrow (p_e - p_{eo}) \uparrow \rightarrow x \downarrow \rightarrow \pi_e^e \downarrow \ldots$

Figure: Dynamic adjustments to a one percent output shock in the 3D model (Y, p_e, π_e^e) and the 4D model (Y, p_e, π_e^e, x) (first two rows) and maximum eigenvalue diagrams (last row) with $s_x < 1/a_x$.

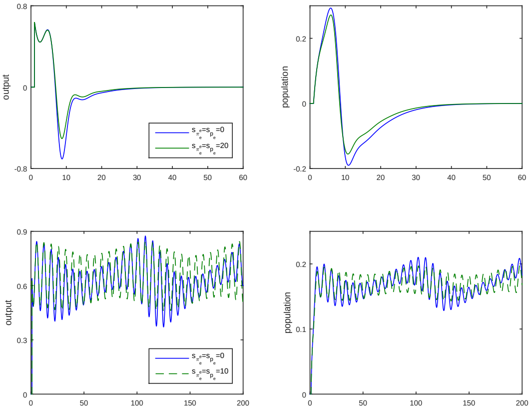


Figure: Dynamic adjustments of output and population shares in the full 4D model (Y, p_e, π_e^e, x) for different values of s_{p_e} and $s_{\pi_e^e}$ for the dynamically stable case (upper panels) and the (locally) unstable case (lower panels).

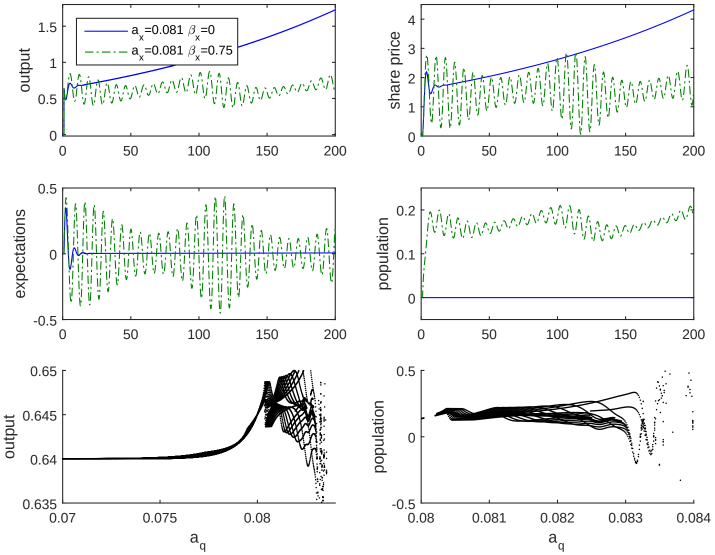


Figure: Explosive dynamics in the 3D model (Y, p_e, π_e^e) versus bounded dynamics in the 4D model (Y, p_e, π_e^e, x).

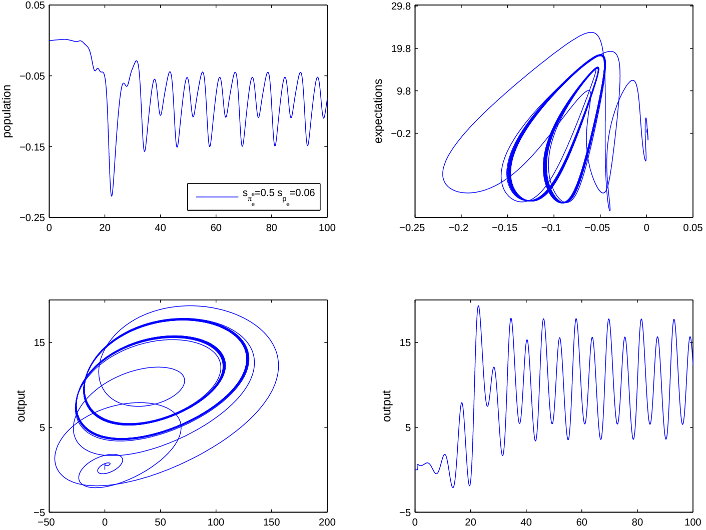


Figure: Complex dynamics in the 4D model (Y, p_e, π_e^e, x).

Policy Intervention

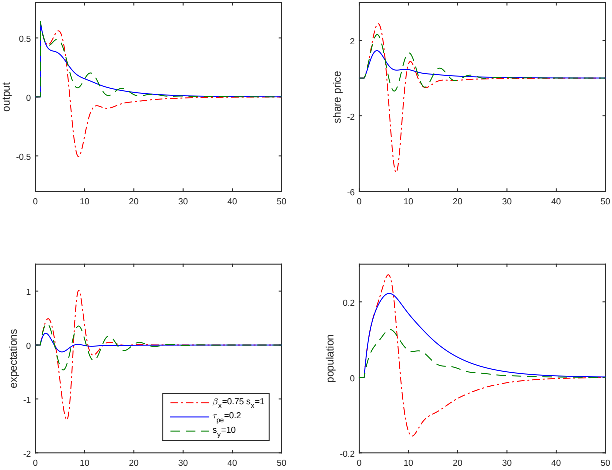


Figure: Dynamics under capital gains taxation and central bank communication policy in the full 4D model (Y, p_e, π_e^e, x).

Conclusions

- Financial side of the economy affects macroeconomic activity through a "Tobinian" accelerator.
- The performance of the real sector influences agents' decisions on financial markets via the profit rate.
  - This interaction leads to instability when the financial sector has strong influence in macroeconomic decisions.
- Aggregate sentiment dynamics between fundamentalists and chartists
  - Increase and amplify fluctuations.
  - Also provide a "stabilising" mechanism that is able to prevent the economy from moving to an explosive path.
- Policy intervention can reduce macrofinancial volatility!

Thank you for your attention

Table: Baseline Parameter Calibration of the 2D model

Autonomous spending	A	0.128
Profit share	b	0.35
Elasticity of aggregate demand to income	a_y	0.8
Elasticity of aggregate demand to Tobin's q	a_q	0.05
Adjustment speed of Tobin's q	β_e	2
Adjustment speed of output	β_y	2
Parameter in population dynamics	a_x	0.8
Steady state capital stock	K_o	1
Steady state equity stock	E_o	1
Steady state population	x_o	0
Steady state expectations	π^e_{eo}	0
Steady state expected capital return	ρ^e_{eo}	0.14
Steady state output capital ratio	$\frac{Y_o}{K_o}$	0.64
Steady state share price	p_{eo}	1.6