Could a post-growth transition trigger a financial market crash? Analysis via a heterogeneous agent model

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Abstract

Climate change mitigation requires large scale and rapid political measures. Assuming that such measures would have diminishing side-effects on economic growth: What impact would such a prospect have on financial market dynamics? This question is analysed using a heterogeneous agent model of a stylized financial market. We consider two scenarios, both starting with the information announcement about lower future dividends. In the first scenario, agents believe that the shock is temporary and that the economy will catch up after a while (as during the Covid-19 pandemic). In the second one, agents believe that the transition to zero growth rates is permanent. Furthermore, in the two scenarios a setup with heterogeneous behaviour is compared with a setup with only fundamental investors in terms of the size and steepness of the asset price drop. Preliminary results show that there is indeed the possibility of a large asset price drop in a transition to a zero-growth economy.

1 Introduction

Climate change mitigation requires a rapid and significant reduction of green house gas emissions [First, 2019], however, the international political measures of the past years are not sufficient to reach this goal [Hoegh-Guldberg et al., 2019].

At the same time, economic growth has been on the top of political agendas for decades [Schmelzer, 2015]. While there are studies showing that some environmental measures have no reducing impact on economic growth [Metcalf and Stock, 2020] there is an ongoing debate about the feasibility of green growth as a sole strategy for reaching climate goals [Parrique et al., 2019]. Independently of this debate, restricting to green growth measures and ruling out all policies that might have diminishing effects on GDP means losing a large potential for averting the climate crisis. In order to open up the possibility of such post-growth policies, the social, economic and financial side-effects of such policies need to be analysed.

This work focusses on the impact of post-growth policies on financial market stability. Could the implementation of environmental policies with the side-effect of lower economic growth (or GDP) trigger a financial market crash? Tokic [2012], claims, that *any indication of the degrowth scenario would cause the stock market to crash* leading to a subsequent economic crisis. So far, this statement has been analysed using an endogenous business cycle model by Barrett [2018] or using an interbank network model by Safarzyńska and van den Bergh [2017]. In both examples, the authors come to the conclusion that a transition to zero growth or degrowth does not lead to an increase in financial or economic instability. However, these two models do not include stock market dynamics. This work contributes by analysing the statement by Tokic [2012] via a stylized heterogeneous agent model of financial asset price dynamics based on the model by Beja and Goldman [1980] with fundamentalists and chartists. The post-growth transition is assumed to translate into constant, i.e. non-growing dividends, in contrast to the exponentially growing dividends in the baseline scenario. This is motivated by the approximately exponential development of actual dividend payments in stock markets, see [Hommes et al., 2017].

The main questions are the following: 1) What is the impact of the announcement of a "post-growth policy" on financial asset prices? 2) How does the impact differ between a model with only fundamentalists and a model including fundamentalists and chartists? 3) To what extent do these dynamics differ from a temporary change in dividends compared to a permanent change in dividends in the post-growth scenario?

In Section 2, a brief literature overview is given, in Section 3 the model is introduced, in Section 4 the results from model analysis and simulation are presented and in Section 5 an interpretation of the model results as well as a sketch for further research steps is provided.

2 Literature

The following branches of literature are relevant for this work: heterogeneous agent models and degrowth economics.

Heterogenous agent models have been successful in explaining many stylized facts about financial markets such as fat tails, volatility clustering or excess volatility that traditional models have had difficulties to explain, [Lux, 2009]. Therefore, a heterogeneous agent approach is chosen in this project. For literature reviews on heterogenous agent models in finance, see Dieci and He [2018] or Hommes [2021].

Although the premise for using heterogeneous agent models is that the assumptions for the efficient market hypothesis does not hold, some HAMs use an externally given fundamental value motivated by rational expectations as an anchor to the price dynamics, e.g. Thurner et al. [2012], Beja and Goldman [1980]. Others use the model of myopic mean variance maximizers, [Brock and Hommes, 1998]. Here, we combine the model dynamics of Beja and Goldman [1980] with fundamental value given by the expected sum of discounted future dividends.

Some recent heterogeneous agent models are build using an evolutionary switching rule between trading rules (heuristics), [Hommes, 2021]. If agents using one type of trading heuristic are more successful, other agents change their strategy towards the successful strategy. However, for short term dynamics as the ones analysed in this paper, heuristic switching rules might not be adequate. Financial market participants such as investment fonds or hedge fonds maintain a certain infrastructure and skill sets to analyse markets and make trading decisions which might not be available to other types of financial market participants such as retail traders. Thus, in particular switching from a low cost to a high cost strategy might not be possible in the short run.

As a first step towards analysing post-growth transition dynamics from a financial market perspective, we adapt the model by Beja and Goldman [1980], which is one of the first heterogeneous agent models in finance. The model is useful due to its clear structure of the two dimensional linear system and analytical tractability. Beja and Goldman [1980] provide an extensive stability analysis for their model.

Literature on degrowth has emerged relatively recently (within the last 15 years, [Weiss and Cattaneo, 2017]). In an increasing number papers, formal models are described, see for example D'Alessandro et al. [2020] or Jackson and Victor [2020]. For reviews on degrowth see Cosme et al. [2017], Weiss and Cattaneo [2017], Kallis et al. [2018]. A related but not equivalent debate to the question posed in this paper is the discussion around monetary growth imperatives. This debate is centered around the question, whether the current monetary system is compatible with constant economic activity (zero-growth), see [Richters and Siemoneit, 2017] for an overview. In particular, the exponential growth scenario is compared to a zero-growth scenario without analysing the transition between the two. In contrast, here, the focus is on the transition dynamics from a growth path to a zero-growth economy including the respective changes in expectations about future developments. Furthermore, variable financial asset prices are modelled which has not been done in the models surveyed in [Richters and Siemoneit, 2017].

3 Model

The model is based on the work by Beja and Goldman [1980] who analyse the price dynamics of a risky asset using a continuous time two dimensional dynamical system with fundamentalists and chartists. This model is adapted into discrete time and used as a basis for the scenario analysis.

Let p_t be the market price of the financial asset at time t, using a discrete time scale $t \in \mathbb{N}_0$. In the definition of the price dynamics in (1), we consider the natural logarithm of the market price p_t, $P_t := \ln p_t$, in order to avoid dealing with negative prices. Log prices change proportionally to excess demand which is calculated as the sum of excess demand by fundamentalists D_t^F and excess demand of chartists D_t^C. It is assumed that fundamentalists buy, if the price is below the perceived fundamental value f_t and sell, if the current price is above the perceived fundamental value. Chartists buy if they perceive the price trend to be positive and sell if they perceive the trend to be negative. The perceived trend ψ_t is updated using an adaptive learning rule in which ψ_t is approaching the current growth rate of the market price p_t. The model can be summarized in the following equations,

$$\begin{aligned} \text{fundamentalists' excess demand} \quad & D_t^F = a\big(\ln(f_t) - P_t\big) \\ \text{chartists' excess demand} \quad & D_t^C = b\psi_t \\ \text{log price} \quad & P_{t+1} = P_t + \frac{1}{\lambda}(D_t^F + D_t^C) \\ \text{perceived trend} \quad & \psi_{t+1} = c\,(P_{t+1} - P_t) + (1-c)\psi_t \end{aligned} \tag{1}$$

with parameters $a, b \geq 0$ describing the fraction or influence of fundamentalists and chartists respectively, and learning parameter $c \in (0, 1]$ for the trend update. Parameter λ can be interpreted as market liquidity, i.e. the higher λ, the lower the impact of excess demand on the price change. For simplicity we set $\lambda = 1$ in the further analysis.

In the original model, the fundamental value F_t is exogenously given. Here, the fundamental value is calculated according to (expected) discounted future dividend payments,

$$f_t = \mathbb{E}_t \left[\sum_{k=1}^{\infty} \frac{d_{t+k}}{(1+r)^k} \right], \tag{2}$$

where r is a constant discount rate, d_{t+k} is the dividend payment at time $t+k$, and $\mathbb{E}_t[\cdot]$ is the expectation operator, conditional on information at time t. The latter is modelled in a simplified way, in which fundamentalists believe future dividends to follow a deterministic path. Three time points are relevant in the model, $0 \leq T_0 \leq T_1 \leq T_2$. In the baseline scenario, fundamentalists believe that dividends grow at a constant rate $\delta_0 > 0$. At time $t = T_0$, fundamentalists receive new information about future dividends, in both scenarios. In scenario 1, they receive the information that dividend payments are reduced (or suspended) between time T_1 and T_2. After time T_2, dividends return to their previous level and growth rate. In scenario 2, the information is announced that dividends stay constant after time T_1 up to infinity. Figure 1 shows the dividend scenarios.

4 Results

Two scenarios are compared, scenario 1 with a temporary change in dividend payments and scenario 2 with a permanent change in dividend payments. In both scenarios, two cases are simulated, one with a fundamentalists only model, and one case with both, fundamentalists and chartists. Figure 2 shows a simulation of the dynamics which illustrates the following characteristics: The inclusion of chartists in the model in general leads to a deeper but less steep price drop.

4.1 Model Analysis

We are interested in the transition dynamics that arise due to the information announcement at time T_0. The questions are:

- How large is the downturn in fundamental values at $t = T_0$ in scenarios 1 and 2?
- How does the existence of chartists impact the price dynamics in scenarios 1 and 2?

In addition, one could also conduct a stability analysis analogous to Beja and Goldman [1980] for the case of constant (non-growing) fundamental values $f(t) = \bar{f} \in (0, \infty)$, although this is not the focus of this paper. Such an analysis allows for a better understanding of the system's dynamics in the whole

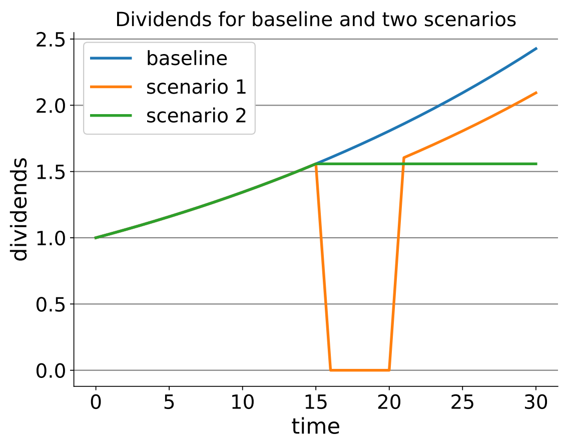

Figure 1: Dividend payments on risky asset. Initial dividend growth rate $\delta_0 = 0.03$. Scenario 1: Dividend decline to zero between $T_1 = 15$ and $T_2 = 20$, after T_2 continuation with dividend growth $\delta_0 = 0.03$ starting again from level at T_1. Scenario 2: Permanent change to zero dividend growth after time $T_1 = 15$.

parameter space. To this end, the system needs to be rewritten into matrix form. As in Beja and Goldman [1980], we get

$$\begin{pmatrix} P_{t+1} \\ \psi_{t+1} \end{pmatrix} = \begin{pmatrix} P_t \\ \psi_t \end{pmatrix} + \underbrace{\begin{pmatrix} -a & b \\ -ac & -c(1-b) \end{pmatrix}}_{=:A} \cdot \begin{pmatrix} P_t \\ \psi_t \end{pmatrix} + a \begin{pmatrix} 1 \\ c \end{pmatrix} \ln f(t), \quad t = 0, 1, 2, ... \tag{3}$$

For A invertible, the unique fixed point of the system (3) is $(P^*, \psi^*) = (\ln(f_t), 0)$, which means that in this case $P_t = P^* = \ln(f_t)$ and $\psi_t = \psi^* = 0$ for all $t = 0, 1, 2, \ldots$. If the eigenvalues of matrix A have absolute value smaller than 1, the fixed point (P^*, ψ^*) is asymptotically stable, i.e. the price P_t is converging to $P^* = \ln(\bar{f})$ over time, [Strogatz, 2018].

For the change in fundamental values at time T_0, an analytical result can be provided. To this end, we compare two fundamental values at a time t, one for a growth scenario f^g and one for a zero-growth scenario f^z. Let f^g be the fundamental value with the expectation of average dividend growth of $\delta_0 = \delta > 0$ and let f^z be the fundamental value with the expectation of zero dividend growth and let us denote the current dividend payment by $d_t > 0$.

Proposition 1. *A change in expected dividend growth from $\delta_0 = \delta > 0$ to $\delta_1 = 0$ leads to a relative change in fundamental values by*

$$\frac{f^g - f^z}{f^g} = \frac{\delta(1+r)}{r(1+\delta)} \approx \frac{\delta}{r} \tag{4}$$

Proof. Using the Gordon model of fundamental values, [Hommes et al., 2017], the two fundamental values f^g and f^z at time t can be computed by

$$f^g = \sum_{k=1}^{\infty} \frac{d_t(1+\delta)^k}{(1+r)^k} = d_t \frac{1+\delta}{r-\delta}$$
$$f^z = \sum_{k=1}^{\infty} \frac{d_t}{(1+r)^k} = d_t \frac{1}{r}.$$

Thus, we get

$$\frac{f^g - f^z}{f^g} = \frac{\frac{1+\delta}{r-\delta} - \frac{1}{r}}{\frac{1+\delta}{r-\delta}} = \frac{r(1+\delta) - (r-\delta)}{r(r-\delta)} \cdot \frac{r-\delta}{1+\delta} = \frac{\delta(1+r)}{r(1+\delta)}.$$

For small values of r and δ, for example for r and δ between zero and 10%, we have

$$\frac{1}{1.1} < \frac{1}{1+\delta} < \frac{1+r}{1+\delta} = \frac{1+\delta+r-\delta}{1+\delta} = 1 + \frac{r-\delta}{1+\delta} < 1+r-\delta < 1.1.$$

Thus, allowing for a deviation in the magnitude of r and δ, we can approximate the result by

$$\frac{\delta(1+r)}{r(1+\delta)} \approx \frac{\delta}{r}.$$

□

Remark: To illustrate this result, consider an average dividend growth of 1.3%, and a constant discount rate of $r = 4.7\%$ as in the empirical analysis by [Hommes et al., 2017] using data from 1951-1012. With these parameters, the relative decline of the fundamental value in a transition to zero dividend growth would be

$$\frac{f^g - f^z}{f^g} \approx 28\%.$$

This decline only includes the effect due to changes in fundamentals. In addition, trend following behaviour and positive feedback dynamics can exacerbate such a price downturn. In comparison, the S&P 500 index fell by 34% in February and March 2020 during the corona pandemic, [Giglio et al., 2021], which already includes all real-world accelerating dynamics.

4.2 Simulation results

Depending on the choice of parameters, the drop in fundamental value can be significantly larger in scenario 2 compared to scenario 1, even if the dividends drop to zero during the time frame T_1 to T_2, and stay constant in scenario 2 after time T_1. However, if the time of zero dividend payments is large enough, the price drop at time T_0 can be identical in both scenarios.

In order to illustrate the behaviour of the model when the system already is in a bubble at time T_0, we modify the system slightly. A bubble is triggered in both scenarios by an overestimation of the price trend by chartists at time $t = 5$ by factor 20. In Figure 3 a simulation run is shown. We see that the information about future lower dividends at time T_0 triggers a price drop which is larger in total compared to the cases without initial bubble.

5 Discussion

In two scenarios, the impact of information about future dividend decline on asset price dynamics in a heterogeneous agent model is analysed. Scenario 1 consists of temporary lower dividends motivated by events such as the corona crash in spring 2020 and scenario 2 consists of a change to permanently constant dividends to be interpreted as a transition to a zero-growth economy. In all scenarios, information arrival at T_0 leads to an asset price drop, which, depending on its size, could be called a financial market crash. Thus, a preliminary result of this work is that the prospect of a transition to a zero-growth economy could indeed cause a large asset price drop. Whether such an asset price decline could lead to contagion dynamics and a financial crisis would need to be analysed using network models, such as used in the systemic risk literature, [e.g. Battiston et al., 2017, Poledna and Thurner, 2016].

There are several directions for next steps. First, the current model only considers two types of agents without further structure connecting them. In real markets, there are other mechanisms that can lead to accelerating dynamics and positive feedback loops such as fire sales and balance sheet contagion, see for a systemic risk perspective of climate policies. Mechanisms such as leverage restrictions and fire sales [Aymanns and Farmer, 2015] or balance sheet networks and systemic risk, [Battiston et al., 2017] could be considered to better understand the dynamics in a post-growth transition. Such mechanisms can amplify the downturn caused by a change in fundamentals.

Second, further analysis is needed to understand to what extend changes in fundamental values defined as sum of expected discounted dividends actually impact on asset prices in the given context. Empirical analysis as in Giglio et al. [2021] can help in this endeavour.

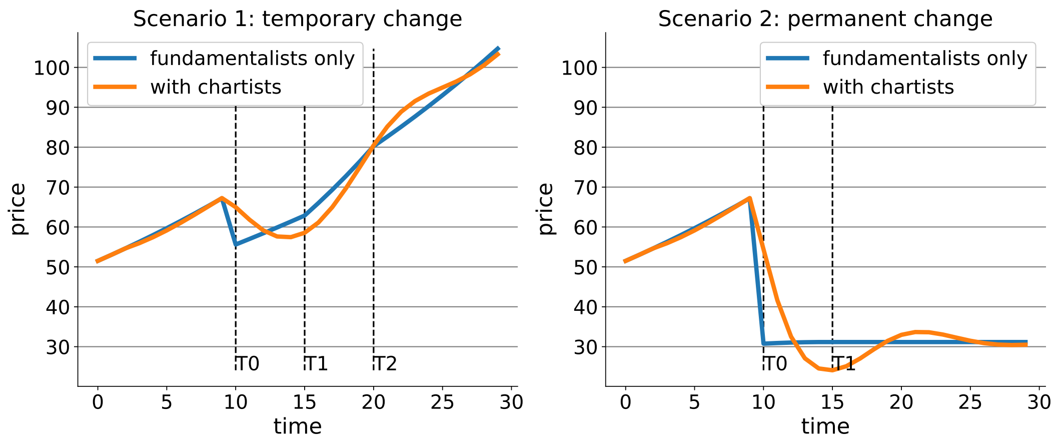

Figure 2: Price dynamics of risky asset in the two scenarios. Scenario 1 with a temporary decline (to zero) in dividends between time $T_1 = 15$ and $T_2 = 20$ and scenario 2 with a permanent change to zero dividend growth after $T_1 = 15$. At $T_0 = 10$ the information about future dividend developments becomes available to fundamentalists. Parameters: $a = 0.3$, $b = 0.7$, $c = 0.7$, $\delta_0 = 0.03$, $r = 0.05$.

Third, a closer look is needed in the model of the fundamental value itself. Which discount rate is used? See for example Adamou et al. [2021] for different models of discounting. Furthermore, it might be useful to consider time varying discount rates. Moreover, heterogeneity in the confidence about political measures and the time of their implementation could be included in the model.

All in all, the presented model needs to be understood as a first step towards understanding transition risk under limits to growth. Nevertheless, the current results indicate, that there is indeed the possibility of a financial market crash in a transition to a post-growth economy.

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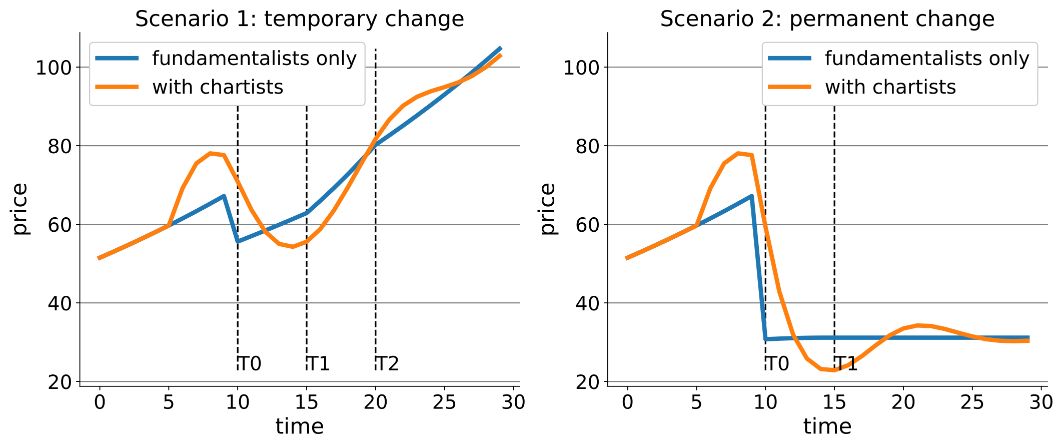

Figure 3: Price dynamics of risky asset in the two scenarios including a bubble at $T_0 = 10$. The bubble is triggered by a trend overestimation at $t = 5$ by chartists by factor 20. Scenario 1 with a temporary decline (to zero) in dividends between time $T_1 = 15$ and $T_2 = 20$ and scenario 2 with a permanent change to zero dividend growth after $T_1 = 15$. At $T_0 = 10$ the information about future dividend developments becomes available to fundamentalists. Parameters: $a = 0.3$, $b = 0.7$, $c = 0.7$, $\delta_0 = 0.03$, $r = 0.05$.

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