Investment Cycles, Strategic Delay, and Self-Reversing Cascades

James Peck and Huanxing Yang

The Ohio State University

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Our starting point is the seminal paper by Chamley and Gale (EC 1994), where

–agents receive a signal correlated with the fixed investment return

–endogenous timing: agents (with favorable signals) can invest or wait and observe market activity.

Chamley and Gale find that the option to wait leads to free riding. There is strategic delay, which is inefficient and stifles information flow.

In large economies with very patient agents (or the time between rounds is small), the only inefficiency is underinvestment. The fraction who invest might be zero, even in the good state, but if a positive fraction of agents invests, it must be the good state.

Chamley and Gale (EC 1994) and Levin and Peck (JET 2008) interpret strategic delay as lengthening recessions, but there are no cycles in these models. Cascades cannot be reversed.

Moscarini, Ottaviani, and Smith (ET 1998) consider an exogenous timing model, where the investment return fluctuates according to a Markov process. Cascades eventually reverse themselves, because of the accumulated probability of a switch in investment return.

Macro Literature: (information is assumed to be symmetric)

In Zeira (RES 1993), maximum (potential) demand follows a random walk, and all that is observed is whether or not potential demand exceeds actual production. Investment is shown to be cyclical.

Veldkamp (JET 2005) has a model with borrowing and default, where the success probability in a given period is either high or low, and the success probability switches with small probability. Success outcomes are publicly observed. In booms, there is a lot of investment, and outcomes are highly informative, so when the state switches we see a sudden crash. In recessions, there is little investment, so when the state switches the outcomes are only moderately informative, so the boom is more gradual.

Our innovation is to embed a fluctuating investment return in an endogenous timing herding model. In each period, a new investment return is determined (high or low), and a new generation of agents receives signals (high or low). In our "Waiting Game," agents can decide whether to invest in round 1 of their period, or wait until round 2 of that period.

Another difference from Chamley and Gale is that agents with low as well as high signals are allowed to invest.

Results:

Characterization of the equilibrium choices in each period, as a function of the beginning-of-period beliefs about the investment state.

Our characterization of equilibrium provides an algorithm for simulating equilibrium paths. Simulations indicate that the option to wait leads to shorter booms (where most agents invest) and longer recessions (where most agents do not invest).

Analytical results about long-run dynamics are available for the large, persistent economy. Booms are shorter and recessions are longer than in the No-Waiting Game. A single investor can have a significant effect on the economy.

Even though cycles include cascades of boom periods in which everyone invests, the Chamley-Gale no-overinvestment result is robust when agents are very patient.

The Waiting Game

n agents per period. Each period has two rounds.

The investment return in period t is common to all investors, and has persistence parameter ρ:

$$\begin{aligned}\Pr(S^t &= 0) = \Pr(S^t = 1) = \frac{1}{2} \\ \Pr(S^{t+1} &= 0 | S^t = 0) = \Pr(S^{t+1} = 1 | S^t = 1) = \rho.\end{aligned}$$

Investment cost is denoted by c.

The realized payoff to an investor in round 1 of period t is $S^t - c$, and in round 2 of period t is $\delta(S^t - c)$, where $\delta < 1$.

Private signals are conditionally independent, with accuracy parameter α:

$$\Pr(s = 0|S^t = 0) = \Pr(s = 1|S^t = 1) = \alpha.$$

We will refer to agents as either type-0 or type-1, depending on whether they receive the low signal or the high signal.

Timing:

At the beginning of period t, the investment state is realized. Each agent observes her signal and the history of past investments, h^{t-1}. Agents simultaneously decide whether to invest or not in round 1. Then agents that did not invest in round 1 observe round 1 investment, and simultaneously choose whether to invest in round 2. After round 2, we proceed to period $t+1$ with a new generation of agents, and so on.

Beliefs:

Beginning-of-period beliefs about the probability of the high investment state are $\mu(h^{t-1})$.

Beliefs conditional on an agent being type-1 or type-0 are

$$\mu_1 \equiv \text{Pr}(S^t = 1|s = 1, \mu) = \frac{1}{1 + (\frac{1-\alpha}{\alpha})(\frac{1-\mu}{\mu})}$$

$$\mu_0 \equiv \text{Pr}(S^t = 1|s = 0, \mu) = \frac{1}{1 + (\frac{\alpha}{1-\alpha})(\frac{1-\mu}{\mu})}.$$

Equilibrium behavior depends on beginning of period beliefs as follows:

Regime 0: Investment is unprofitable for type-1 agents, so no one invests in round 1, nothing is learned so no one invests in round 2.

Regime M: Investment is profitable for type-1 agents, but not as profitable as waiting and learning everyone's signal, so not all type-1 agents can invest. Type-1 agents mix. Round 2 behavior depends on round 1 investment.

Regime 1: Type-1 agents prefer investing to waiting and learning everyone's signal, so they invest in round 1, but type-0 agents prefer to wait. Round 1 reveals all signals, and round 2 behavior depends on round 1 investment.

Regime 2: Type-0 agents prefer investing to waiting and learning everyone's signal, so everyone invests in round 1. Nothing is learned during this period.

In computing the mixing probability and round 2 behavior, it is important to compute beliefs in round 2, when the mixing probability is q and k agents invest in round 1 (outside observer, type 1, and type 0 resp.):

$$\mu^{k,q} = \frac{1}{1+\frac{1-\mu(h^{t-1})}{\mu(h^{t-1})}(\frac{1-\alpha}{\alpha})^{k}(\frac{1-(1-\alpha)q}{1-\alpha q})^{n-1-k}}$$

$$\mu_1^{k,q} = \frac{1}{1+\frac{1-\mu(h^{t-1})}{\mu(h^{t-1})}(\frac{1-\alpha}{\alpha})^{k+1}(\frac{1-(1-\alpha)q}{1-\alpha q})^{n-1-k}}$$

$$\mu_0^{k,q} = \frac{1}{1+\frac{1-\mu(h^{t-1})}{\mu(h^{t-1})}(\frac{1-\alpha}{\alpha})^{k-1}(\frac{1-(1-\alpha)q}{1-\alpha q})^{n-1-k}}$$

Proposition (3.2) gives a full characterization of equilibrium. Cutoff beliefs for each regime, equilibrium strategies within each regime, and evolution of beliefs are specified.

Proposition (3.3) compares the regime cutoffs for the Waiting Game and the No-Waiting Game, and shows that Regime 0 cascades and Regime 2 cascades are self-reversing.

Long-Run Patterns of Boom and Recession

Given the symmetry assumptions of states and signals, it is reasonable to define a boom to be a period in which at least half of the agents invest, and a recession to be a period in which less than half of the agents invest.

Simulations indicate that the Waiting Game has longer recessions and shorter booms than the No-Waiting Game.

The Waiting Game has more underinvestment and less overinvestment than the No-Waiting Game.

Welfare is often higher without the option to wait.

The Large, Persistent Economy

For the Waiting Game, assume that $n \to \infty$, so that learning all signals can be taken to reveal the investment state with certainty. Fix ρ near 1.

Then the equilibrium cycle can be described as follows (start after the investment state is revealed to be low):

–We enter a Regime 0 cascade, which persists for many periods as beliefs slowly rise to the zero-profit level for a type-1 agent.

–When type-1 profits from investment in round 1 first become positive, investment is only *slightly* profitable. We enter Regime M, where $q \to 0$ as $n \to \infty$, such that the probability of zero investment in round 1 is nearly one.

Intuition: Because profits from investing are only slightly positive, the value of any information received by waiting must be very small, so

(i) conditional on no round-1 investment, type-1 profits in round 2 remain near zero, and we are back where we started, and

(ii) this event must be very likely.

–When the mixing outcome leads to zero round-1 investment (most likely), no one invests in round 2, and we have the same initial beliefs in period $t + 1$ as period t. We stay in Regime M.

–In Regime M, if round-1 investment is exactly one, then the remaining type-1 agents invest in round 2, but not the type-0 agents, *revealing the investment return*.

–In Regime M, the probability of round-1 investment being greater than one negligible.

–In Regime M, if round-1 investment is one and the investment state is revealed to be low, we begin another Regime 0 cascade.

–In Regime M, if round-1 investment is one and the investment state is revealed to be high, we enter a Regime 2 cascade.

–During a Regime 2 cascade, beliefs about the investment state slowly fall until we enter Regime 1.

–In Regime 1, the investment return is revealed, either starting another Regime 2 cascade (most likely) or starting a Regime 0 cascade.

As $\rho \longrightarrow 1$, the number of periods in a Regime 0 cascade, the number of periods in a Regime 2 cascade, and the expected number of periods to leave Regime M become unbounded, but the limiting boom and recession probabilities are well defined. Recessions are longer and booms are shorter, as compared to the No-Waiting Game.

In the large, patient persistent economy, as $\rho \longrightarrow 1$ and $\delta \longrightarrow 1$, the number of periods in a Regime 2 cascade has a finite limit. Thus, booms are characterized by a sequence of many Regime 2 cascades, explaining why there is very little overinvestment.

Conclusions

The option to delay investment will tend to lengthen recessions and shorten booms.

Private information gets aggregated by market activity, but imperfectly and in chunks.

A single investor can get the ball rolling and have a large impact, even in a large economy.