Crises and Information

Universität Trier, Department of Economics

Guest Lecture by Rick Fernholz

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A Simple Coordination Game

- The economy is populated by many small investors.
- The investors are indexed by $i \in [0, 1]$.
- Each investor has 1 peso, and can either sell his peso for 1 euro or do nothing and hold onto his peso.
- If the peso is devalued, then 1 peso is equal to 0.5 euros (so that also 1 euro $=$ 2 pesos). If not, then 1 peso remains equal to 1 euro.
- The cost of exchanging 1 peso for 1 euro is r pesos, where $0 < r < 1$.
- If the peso is devalued, then an investor who sells the peso has $2 - r$ pesos and an investor who does nothing has 1 peso.
- If the peso is not devalued, then an investor who sells the peso has $1 - r$ pesos and an investor who does nothing has 1 peso.

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Coordination Game: Payoffs

	Devaluation	No Devaluation
Sell	2 - r	1 - r
No Sell	1	1

- The payoffs for this game are:
  - An investor who sells the peso receives $2 - r$ pesos if there is a devaluation and $1 - r$ pesos if there is no devaluation.
  - An investor who does not sell the peso receives 1 peso no matter what.
- Remember that $0 < r < 1$, so that also $1 - r < 1 < 2 - r$.
- Then, investors only exchange pesos for euros if they think that there will be a devaluation of the peso.

Coordination Game: Notation

- Let $a_i = 1$ denote a sale of 1 peso by investor i, and $a_i = 0$ denote no action by investor i (hold onto the peso).
- Let A be the fraction of investors that sell the peso, so $A = \int_0^1 a_i \, di$.
- It is always true that $0 \leq A \leq 1$.
- Let $\theta \in \mathbb{R}$ be the fundamentals of the Mexican economy.
- Suppose that the peso is devalued only if many investors sell the peso.
- Specifically, suppose that the peso is devalued if and only if $A \geq \theta$.
- If $\theta > 1$, then the peso will not be devalued even if all investors exchange it for euros. The Mexican economy has good fundamentals.
- If $\theta < 0$, then the peso will be devalued even if no investors exchange it for euros. The Mexican economy has weak fundamentals.

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Self-Fulfilling Crises

- There is a devaluation if and only if $A \geq \theta$.
- Remember that $A = 1$ if all investors sell their pesos and $A = 0$ if no investors sell their pesos.
- If $0 < \theta < 1$, it is possible both for a devaluation to occur (if all investors decide to sell their pesos) and for a devaluation not to occur (if no investors decide to sell their pesos).
- In an equilibrium of this game, investors choose to sell their pesos only if they think a devaluation will occur.
- If investors all know θ, and $0 < \theta < 1$, then there are two equilibria:
  1. All investors sell their pesos ($A = 1 > \theta$ and there is a devaluation).
  2. No investors sell their pesos ($A = 0 < \theta$ and there is no devaluation).
- Through their actions, investors "choose" if there will be a crisis.

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Unique Monotone Equilibrium

Suppose that investors do not know the value of the Mexican economy's fundamentals θ. Instead, each investor i privately observes $x_i = \theta + \varepsilon_i$, where $\varepsilon_i \sim \mathrm{N}(0, \sigma^2)$. This observation represents the private information of investor i since he does not observe x_j if $i \neq j$.

Theorem

Then, there exists a unique equilibrium of this game in which each investor i sells his peso if and only if $x_i \leq x^*$ and a devaluation of the peso occurs if and only if $\theta \leq \theta^*$, where x^* and θ^* are given by the solution to

$$\theta^* = \Phi\left(\frac{x^* - \theta^*}{\sigma}\right) \qquad \text{and} \qquad r = 1 - \Phi\left(\frac{x^* - \theta^*}{\sigma}\right).$$

This implies that $\theta^* = 1 - r$ and $x^* = 1 - r + \sigma\Phi^{-1}(1 - r)$.

Monotone Equilibrium: Intuition

- This result is from a very important paper by Morris and Shin (1998).
- In equilibrium, investors sell their pesos only if they are pessimistic about the Mexican economy's fundamentals.
- In the notation of this game, this is the case in which $x_i \leq x^*$.
- Since each investor's optimism is increasing in his private signal x_i, any investor that privately observes x^* must be indifferent between selling or holding a peso: $r = P(\theta \leq \theta^* \mid x^*)$.
- Since the number of investors who sell the peso A is decreasing in the goodness of the Mexican economy's fundamentals θ, any time fundamentals are given by θ^* the number of investors who sell must equal this value of fundamentals: $\theta^* = A(\theta^*) = P(x_i \leq x^* \mid \theta^*)$.

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An Example

- To better understand monotone equilibria, consider a simple example.
- Suppose that each person in this room has €10 worth of Greek bonds.
- Everyone simultaneously decides whether or not to sell their bonds.
- Greece has bad fundamentals, so if any person in the class sells their bonds then Greece will default and all the bonds will be worthless.
- If nobody sells, then the Greek bonds all pay €11.
- It is clearly best for nobody to sell their Greek bonds, but it is very likely that someone in the class will sell because they are worried that someone else will either sell or think that someone else will sell...
- But if Greece has good fundamentals, so that 10 people must sell their bonds for a default, it is unlikely that there is a default.
- Both fundamentals and strategic uncertainty affect the crisis outcome.

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The Real World 1

- In 1992, the British pound was pegged to the Deutsche mark as part of the pre-euro European Exchange Rate Mechanism (ERM).
- By summer, the UK was facing mounting speculative pressure as investors sold pounds and bet that the pound would be devalued.
- In order to conceal the weak state of the UK economy, the British Treasury hid information about its vulnerability to higher interest rates while emphasizing its vast foreign exchange reserves.
- Ultimately, these tactics proved ineffective and the British pound was devalued in the face of massive speculative selling.
- The British Treasury lost 3.3 billion pounds by unsuccessfully defending the pound against speculative attack.

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The Real World 2

- It has recently been discovered that the Bank of Greece hid information and misled investors about the level of its debt in the months and years leading up to the current crisis.
- These actions were deliberate and sophisticated, and relied upon the expertise and savvy of Goldman Sachs, among others.
- Given that central banks manipulate the information that reaches investors during crises, what can models of crises and global games say about this manipulation?
- Does the manipulation of information matter?
- How might it affect the actions of investors?
- Can it be effective or will it usually backfire?

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Information Manipulation in Global Games

- To answer these questions, consider the game from earlier:
  - Investors are indexed by $i \in [0,1]$, where $a_i = 1$ represents a sale.
  - Fundamentals are given by $\theta \in \mathbb{R}$.
  - There is a devaluation if and only if $A \geq \theta$, where $A = \int_0^1 a_i \, di$.
- If investors have private information about θ, then there is a unique equilibrium in which each investor i sells if and only if $x_i \leq x^*$ and there is a devaluation if and only if $\theta \leq \theta^*$.
- Suppose that the central bank takes a costly, hidden action $\nu(\theta) \geq 0$ that biases the investors' information:
  - Investor i observes $x_i = \theta + \nu(\theta) + \varepsilon_i$, where $\varepsilon_i \sim \mathrm{N}(0, \sigma^2)$.
  - Investors do not know the value of $\nu(\theta)$, but in equilibrium it is a function of fundamentals so that investors know something about it.
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The Effects of Information Manipulation 1

- How do θ^* and θ^*_M compare?
- A lower value of θ^* implies a smaller speculative attack on average.
- If the central bank knows the value of fundamentals θ perfectly, then it will never manipulate information if $\theta < \theta^*_M$.
- Suppose that the cost of manipulation is $C(\nu) = k\nu$, with $k > 0$.
- Then, it can be shown that the central bank chooses $\nu(\theta)$ such that

$$\theta + \nu(\theta) = \begin{cases} \theta & \text{if } \theta < \theta^*_M, \\ \theta^*_M + \delta_u & \text{if } \theta^*_M \leq \theta \leq \theta^*_M + \delta_u, \\ \theta & \text{if } \theta^*_M + \delta_u < \theta, \end{cases}$$

  where $\delta_u > 0$ depends on the parameters of the model.
- The bank manipulates information only for intermediate values of θ.

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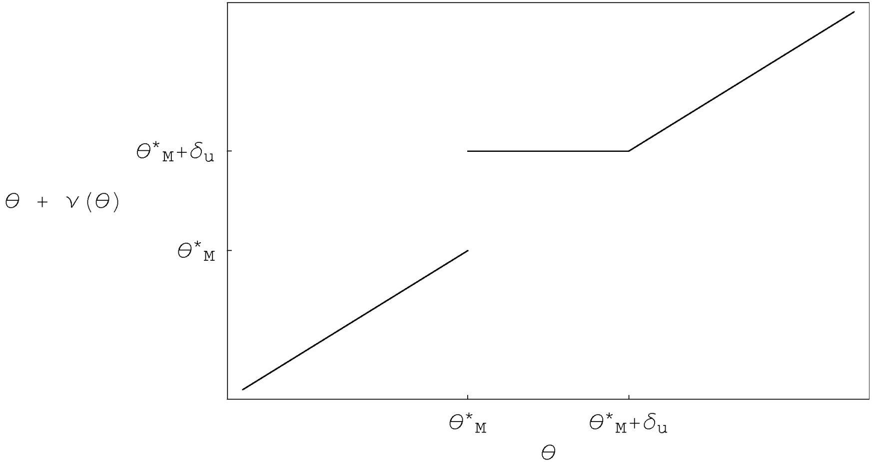
Information Manipulation, Visually 1



The Effects of Information Manipulation 2

- How do θ^* and θ_M^* compare?
- In order to determine the value of θ_M^*, we again solve for the usual indifference conditions:
  - $\theta_M^* = A(\theta_M^*) = P(x_i + \nu(\theta_M^*) \leq x^* \mid \theta_M^*)$
  - $r = P(\theta \leq \theta_M^* \mid x^*)$
- A little bit of algebra then yields the equation

$$r = \frac{\Phi\left(-\frac{\delta_h}{\sigma} - \Phi^{-1}(\theta_M^*)\right)}{\Phi\left(-\frac{\delta_h}{\sigma} - \Phi^{-1}(\theta_M^*)\right) + \frac{\delta_h}{\sigma}\phi(\Phi^{-1}(\theta_M^*)) + \theta_M^*}.$$

- Edmond (2008) shows that as the investors' information becomes very precise ($\sigma \to 0$), θ_M^* converges to zero so that $\theta_M^* < \theta^*$.
- Information manipulation is predicted to weaken speculative attacks.

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Central Bank Uncertainty?

- The previous result relies crucially on the assumption that the central bank knows the state of fundamentals θ perfectly.
- This ensures that only those central banks that will survive a speculative attack manipulate information.
- In the real world, of course, a central bank does not know if it will survive before it makes this decision.
- Suppose that the central bank does not know the value of θ perfectly.
- It can be shown that the bank now chooses $\nu(\theta)$ such that

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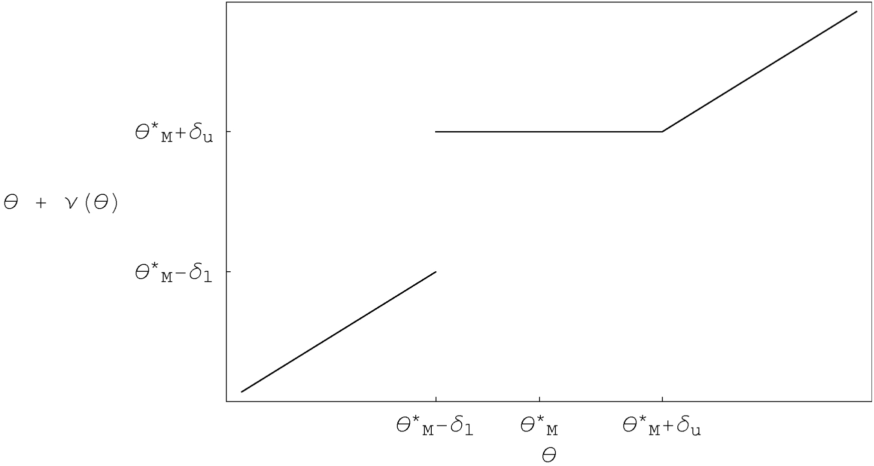

The Effects of Information Manipulation 3

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The Real World, Again

- Like the UK, the Swedish krona was pegged to the Deutsche mark as part of the European Exchange Rate Mechanism in 1992.
- And, again like the UK, Sweden began to face mounting speculative pressure in the summer of 1992 as investors sold the krona and bet on a devaluation throughout Scandinavia.
- Unlike the UK, however, Sweden aggressively raised interest rates to defend the krona. This defense was so intense that interest rates on interbank loans were briefly raised as high as 500%.
- Although the Swedish Riksbank was able to successfully defend the krona from an initial speculative attack in September, a second attack in November led to a quick devaluation.
- This example is different from Greece and the UK because the Riksbank communicated rather than manipulated information.

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Signalling in Global Games

- The idea is that the Swedish Riksbank, by raising interest rates so high, signalled something to investors about its willingness to defend the krona and the fundamentals of the Swedish economy.
- But what did it signal? Strength? Weakness?
- A nice paper by Angeletos, Hellwig, and Pavan (2006) examines this question using the simple global game model presented in this lecture.
- They extend the model so that the central bank can alter the cost of selling r depending on the state of fundamentals θ.
- Investors observe r and then rationally infer something about θ.
- An increase in r is costly to the central bank, reflecting the reality that higher interest rates often cause great economic harm.

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Policy Traps and Self-Fulfilling Equilibria

- The main prediction of the model of Angeletos, Hellwig, and Pavan (2006) is that there are multiple self-fulfilling equilibria if the central bank's choice of policy is a signal of θ.
- This occurs because the central bank's optimal interest rate policy is determined entirely by the investors' interpretation of that policy.
- If investors interpret an increase in interest rates as a sign of strength, then the central bank will indeed raise rates in certain situations.
- In particular, this occurs for intermediate values of fundamentals since the size of a speculative attack matters less when fundamentals are either very strong or very weak.
- If investors interpret an increase in interest rates as a sign of weakness, then the central bank will never raise interest rates.

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What about Public Information?

- The result that public signalling in global games can lead to multiple equilibria is a consequence of a more general result.
- Consider the coordination game from today's lecture and suppose that all investors know the value of fundamentals θ perfectly.
- In this game, as long as $0 < \theta < 1$, there are always two equilibria:
  1. Everyone sells and there is a devaluation.
  2. Nobody sells and there is no devaluation.
- If there is a public source of information, it might be possible for investors to coordinate their actions in this way.
- This is a crucial issue because it determines whether or not fundamentals are an important cause of crises.
- Indeed, one of global games' most significant predictions is that bad fundamentals rather than self-fulfilling beliefs are at the root of crises.

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Global Games with Public Information

- Hellwig (2002) shows that if public information about fundamentals is precise enough, then there are always two equilibria much like the two extreme equilibria when information is perfect.
- In particular, he extends the global game from earlier so that, in addition to their private information, investors also observe public information about θ given by $z = \theta + \eta$, where $\eta \sim \mathrm{N}(0, \sigma_\eta^2)$.
- As in the standard global game, x^* and θ^* are given by the solution to

$$\theta^* = A(\theta^*) = P(x_i \leq x^* \mid \theta^*) \qquad \text{and} \qquad r = P(\theta \leq \theta^* \mid x^*, z).$$

- In equilibrium, investors consider both their private information x_i and the public information z when forming their beliefs about θ.
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Solving the Model

- The first equation implies that

$$\theta^* = P(\theta^* + \varepsilon_i \leq x^*) = \Phi\left(\frac{x^* - \theta^*}{\sigma_\varepsilon}\right),$$

  so that $x^* = \theta^* + \sigma_\varepsilon \Phi^{-1}(\theta^*)$.

- The distribution of θ conditional on observing x^* and z is normal with mean $\frac{\sigma_\eta^2}{\sigma_\varepsilon^2+\sigma_\eta^2}x^* + \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2+\sigma_\eta^2}z$ and variance $\frac{\sigma_\varepsilon^2\sigma_\eta^2}{\sigma_\varepsilon^2+\sigma_\eta^2}$.
- Then, the second equation implies that

$$\begin{aligned} r &= P(\theta \leq \theta^* \mid x^*, z) \\ &= \Phi\left(\frac{\sqrt{\sigma_\varepsilon^2 + \sigma_\eta^2}}{\sigma_\varepsilon\sigma_\eta}\left(\theta^* - \frac{\sigma_\eta^2}{\sigma_\varepsilon^2 + \sigma_\eta^2}x^* - \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_\eta^2}z\right)\right). \end{aligned}$$

Public Information and Multiple Equilibria

- The equations from above imply that θ^* is given by the solution to

$$\frac{\sigma_\varepsilon \sigma_\eta}{\sqrt{\sigma_\varepsilon^2 + \sigma_\eta^2}} \Phi^{-1}(r) = \theta^* - \frac{\sigma_\eta^2}{\sigma_\varepsilon^2 + \sigma_\eta^2} x^* - \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_\eta^2} z$$

$$= \frac{\sigma_\varepsilon^2}{\sigma_\varepsilon^2 + \sigma_\eta^2}(\theta^* - z) - \frac{\sigma_\eta^2 \sigma_\varepsilon}{\sigma_\varepsilon^2 + \sigma_\eta^2} \Phi^{-1}(\theta^*).$$

- Because $\Phi^{-1'}(\cdot) \geq \sqrt{2\pi}$, the right hand side of this equation is decreasing in θ^* for all θ^* and all z if and only if $\sigma_\eta^2 / \sigma_\varepsilon \leq \sqrt{2\pi}$.
- It follows that there is a unique solution to this equation for any z if and only if this condition holds.
- Not surprisingly, it can be shown that there also is a unique equilibrium of this game if and only if this condition holds.

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Prices and Public Information

- The basic, central message of this result about public information and multiple equilibria is one of caution.
- The predictions of models of crises and global games quickly change as the ratio of public to private information changes.
- If there are important sources of public information, then self-fulfilling beliefs might cause more crises than bad fundamentals.
- One interesting implication of this relates to the role of prices as sources of information about market fundamentals.
  - Intrade is a good example.
- If the price of an asset provides investors with information about the asset's true value, then the price is a public source of information.
- If that information is precise enough, this could generate multiple equilibria as in the model we just looked at.

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Prices and Private Information

- In fact, there is even more reason to think that prices might be an important source of public information during crises.
- If investors are rational and have precise private information, then they will trade aggressively and take advantage of that information.
- But that means that the price will contain very good information about fundamentals.
- Thus, as the investors' private information improves, the public information available in prices improves as well.
- In other words, a self-fulfilling crisis becomes more and more likely even as private information improves.
- This result is elegantly presented by Angeletos and Werning (2006) and Hellwig, Mukherji, and Tsyvinski (2006).

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Implications for Central Banks

- Unless fundamentals are very bad, the existence of multiple equilibria and the possibility of self-fulfilling crises is very undesirable.
- Central banks manipulate asset prices often and for many reasons.
- This is particularly true for exchange rates.
- See Calvo and Reinhart (2002), for example.
- In theory, then, it is possible for central banks to manipulate asset prices in such a way that the prices are less informative about fundamentals and the possibility of self-fulfilling crises is eliminated.
- Chamley (2003) presents a nice formal model with some of these ideas in it.

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Monotone Strategies in Practice

- It is very difficult to measure the quality of public and private information about fundamentals.
- Also, models of crises and global games are highly stylized and probably should not be taken directly to data to see when there might or might not be multiple equilibria.
- Fortunately, some initial experimental work by Heinemann, Nagel, and Ockenfels (2009) is encouraging.
- They show that people often play monotone strategies in coordination games as predicted by models of global games.

Dynamic Games

- Crises and many other economic phenomena often change and develop over time.
- Also, the people that take part in these events often learn and change their actions and strategies over time.
- It is essential, then, that models of crises and global games take into account these realistic and important dynamics.
- Some nice examples of progress in this direction is research by Angeletos, Hellwig, and Pavan (2007), Chamley (2003), and Dasgupta (2007).

The End

Thank You