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Volume 3  equality – Hennipman
Proposition. The demand function $f$ satisfies

\begin{align*}
(a) & \quad g(a, b, c) = c, \quad a > 0 \\
(b) & \quad f(a, b, c) = b \\
(c) & \quad f(a, b, c) = f(b, c) \quad \lambda > 0 \\
(d) & \quad f \text{ is smooth.}
\end{align*}

A pure exchange economy will be a set of $m$ traders, each with preferences as discussed above, associated to utility functions $u_i, i = 1, \ldots, m$ defined on the same commodity space $\mathbb{R}_+$. Associated to the $i$th trader is an endowment vector $e_i \in \mathbb{R}_+$. At prices $p$, this trader's wealth is the value of his endowment $p \cdot e_i$. A state is an allocation $(x_1, \ldots, x_m), x_i \in \mathbb{R}_+$ and a pricing system $p \in \mathbb{R}_+$. Feasibility is the condition:

$$\sum x_i = \sum e_i$$

A kind of satisfaction condition of a state is

$$(S) \quad \text{For each } i, \text{ maximaizes } u_i \text{ on the budget set } B = \{ y \in \mathbb{R}_+: p \cdot y = p \cdot e_i \}.$$  

An economic equilibrium of a pure exchange economy $(e_1, \ldots, e_m, u_1, \ldots, u_m)$ is a state $(x_1, \ldots, x_m)$, $x_i \in \mathbb{R}_+$, $p \in \mathbb{R}_+$ satisfying $(F)$ and $(S)$.

Theorem. There exists a price equilibrium of every pure exchange economy.

The proof goes by applying the previous existence theorem above. Define the excess demand $Z = D - S$ as follows:

$$S(p) = \sum e_i, D(p) = \sum f_i(p, p \cdot e_i),$$

where $e_i$ is the above defined demand of the $i$th trader. One then shows Walras's Law:

$$p \cdot S(p) = p \cdot D(p) = p \cdot S(p)$$

using (b) of the proposition above.

Let us first examine the Nash equilibria of this game when $\theta$ is common knowledge. If $\theta < \theta$, then 'invest' is a strictly dominated action for each player, and thus 'not invest', not 'invest' is the unique Nash (and dominant strategies) equilibrium. If $\theta > \theta$, then 'not invest' is a strictly dominated action for each player, and 'invest', 'invest' is the unique Nash (and dominant strategies) equilibrium. The multi-ple case arises if $0 < \theta < 1$. In this case, there are two strict Nash equilibria (both not invest and both invest) and there is also a strictly mixed Nash equilibrium.
global games

games

Notation for games games often have multiple Nash equilibria. Game theorists have long been interested in the use of paying off the derivative of (1) is strictly decreasing in $k$. Thus, if $b(k)$ decreases, player 2 will invest if and only if $x < b^*(0)$. She invests if $x > b^*(1)$. Suppose player 1 invests in the game where $b^*(k) = b'(b^*(0), b^*(k))$. The key intuition for this example is that the uniform prior assumption guarantees that player 1, whatever his signal, attaches probability 1 to his opponent having a higher signal and probability 1 to him having a lower signal. This property remains true no matter how small the noise is, but breaks discontinuously in the limit: when noise is zero, he attaches probability 1 to his opponent having the same signal.

In this article, I will first report how Carlson and van Damme's (1993) analysis can be used to give a complete general analysis of two-player action games. I will then report in turn theoretical extensions of their work and a literature that has used insights from global games in economic applications. This dichotomy is somewhat arbitrary (many applied papers have significant theoretical contributions) but convenient.

1 Two-player, two-action games

Let the payoff of a two-player, two-action game be given by the following matrix:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Invest</td>
<td>$b_1$</td>
<td>$b_2$</td>
</tr>
<tr>
<td>0, 0</td>
<td>$b_3$</td>
<td>$b_4$</td>
</tr>
<tr>
<td>0, 1</td>
<td>$b_5$</td>
<td>$b_6$</td>
</tr>
</tbody>
</table>

Thus a vector $\theta \in \mathbb{R}^2$ describes the payoffs of the game and is drawn from some distribution. For a generic choice of $\theta$, there are three possible configurations of Nash equilibria.

1. There is a unique Nash equilibrium with both players using strictly mixed strategies.
2. There is a unique strict Nash equilibrium with both players using pure strategies.
3. There are two pure strategy Nash equilibria and one strictly mixed strategy Nash equilibrium.

In the last case, Harshany and Selten (1988) proposed the criterion of risk dominance to select among the multiple Nash equilibria. Suppose that $(A, A)$ and $(B, B)$ are strict Nash equilibria of the above game (that is, $\theta_1 > \theta_2, \theta_3 > \theta_4, \theta_5 > \theta_6$ and $\theta_7 > \theta_8$). Then $(A, A)$ is a risk-dominant equilibrium if

$$(\theta_1 - \theta_2, \theta_3 - \theta_4) > (\theta_5 - \theta_6, \theta_7 - \theta_8).$$

Genetically, exactly one of the two pure Nash equilibria will be risk dominant.

Now consider the following incomplete information game $G_0$. Each player observes a signal $x_i = x + \sigma_i$, where the $\sigma_i$ are eight-dimensional noise terms. Thus we

But suppose the players do not exactly observe $\theta$. Suppose for convenience that each player believes that $\theta$ is uniformly distributed on the real line (thus there is an ‘improper’ prior with infinite mass: this does not cause any technical or conceptual difficulties as players will always condition on signals that generate ‘proper’ posteriors). Suppose that each player observes a signal $x_i = \theta + \sigma$, where each $\sigma_i$ is independently normally distributed with mean 0 and standard deviation 1.

In this game of incomplete information, a pure strategy for player $i$ is a mapping $s_i : \mathbb{R} \rightarrow \{\text{Invest}, \text{Not invest}\}$ Suppose player 1 was sure that player 2 was going to follow a ‘threshold’ strategy where she invested only if her signal were above $k$, so

$$s_1(x_1) = \begin{cases} \text{Invest, if } x_1 > k \\ \text{Not invest, if } x_1 \leq k \end{cases}$$

What is player 1’s best response? First, observe that his expectation of $\theta$ is $x_1$. Second, note that (under the uniform prior assumption) his posterior on $\theta$ is normal with mean $x_1$ and variance $\sigma^2$, and thus his posterior on $x_1$ is normal with mean $x_1$ and variance $2\sigma^2$. Thus his expectation that player $j$ will not invest is $\Phi(x_1/k - x_1)$, where $\Phi$ is cumulative distribution of the standard normal. Thus his expected payoff is

$$x_1 - \Phi \left( \frac{1}{\sqrt{2\sigma}} (k - x_1) \right),$$

and player 1 will invest if and only if (1) is positive. Now if we write $b(k)$ for the unique value of $x_1$ setting (1) equal to 0 (this is well defined since (1) is strictly increasing in $x_1$), the best response of player 1 is then to follow a cut-off strategy with threshold equal to $b(k)$.

Observe that as $k \rightarrow -\infty$, $b(k) \rightarrow -\infty$, (player 2 always invests), (1) tends to $x_1$, so $b(k) \rightarrow 0$. As $k \rightarrow \infty$ (player 2 never invests), (1) tends to $x_1 - 1$, so $b(k) \rightarrow 1$. Also observe that if $k = 0$, then $b(k) = 0$, since if player 1 observes signal $0$, his expectation of $\theta$ is $0$ but assigns probability $1$ to player 2 not investing. Finally, observe that (by total differentiation)

$$b'(k) = \frac{1}{1 + \frac{2\sigma}{\sqrt{2\pi}(k - x_1)^{1/2}}} \in (0,1),$$

so $b(k)$ is strictly increasing in $k$ and we can immediately conclude that there is a unique ‘threshold’ equilibrium where each player uses a threshold of 0.

The strategy with threshold 0 is in fact the unique strategy surviving iterated deletion of (interim) strictly dominated strategies. In fact, a strategy $s$ survives $n$ rounds of iterated deletion of strictly dominated strategies if and only if

$$s(x) = \begin{cases} \text{Invest, if } x > b^*(1) \\ \text{Not invest, if } x < b^*(0) \end{cases}$$

where $b^*(k) = b(b^*(0), b^*(k))$.

Therefore, the strategy is a ‘threshold’ equilibrium where both players invest if and only if $x > b^*(1)$

Reference


have an incomplete information game parameterized by a $\sigma \geq 0$. A strategy for a player is a function from possible signals $\mathcal{S}^n$ to the action set $\{A, B\}$. For any given strategy profile of players in the game $G(\sigma)$ and any actual realization of the payoffs $\theta$, we can ask what is the distribution over action profiles in the game (averaging across signal realizations).

**Theorem** For any sequence of games $G(\sigma')$ where $\sigma' \rightarrow 0$ and any sequence of equilibria of those games, average play converges at almost all payoff realizations to the unique Nash equilibrium (if there is one) and to the risk dominant Nash equilibrium (if there are multiple Nash equilibria).

This is shown by the main result of Carlson and van Damme (1993) in cases (2) and (3) above. They generalize the argument from the example described above to show that, if an action $a$ is part of a risk dominant equilibrium or a unique strict Nash equilibrium of the complete information game $\theta$, then -- for sufficiently small $\sigma$ -- that action is the unique action surviving iterated deletion strictly dominated strategies. Kajii and Morris (1997) show that, if a game has a unique correlated equilibrium, then that equilibrium is 'robust to incomplete information', that is, will continue to be played in some equilibria if we change payoffs with small probability. This argument can be extended to show the theorem for case (1) (the extension is discussed in Morris and Shin, 2003).
they are able to present a complete analysis with many players, asymmetric payoffs and payoffs. In particular, a limit uniqueness result player observes the state with noise, and the the result is then, in the limit there is a strategy profile surviving iterated deletion of dominated strategies. Note that while Carlson strategy required no strategic complementarity or monotonicity properties, when there are multiple dominated strategies in a two-player, two-action game – the case for Jonsson and van Damme's analysis – there is no strategic complementarity. This class of monotonic global games where uniqueness holds, Frankel, Morris and Pauzner provide sufficient conditions for 'noise indecision'. That is, for some complete information on which action gets played in the limit as noise does not depend on the steps of the noise. (Franks and Pauzner, 2003) show that a given the potential maximizing action profile is noise independent selection. This sufficient encompasses the risk dominant selection in binary action games, the selection of the action (a best response to a uniform distribution of actions) in many player, binary action games (franks and Shin, 2003). It also yields unique in the stationary player currency crisis model of Morris and Pauzner 's with symmetric payoffs. Morris and Ul'rich further sufficient conditions for equilibria to 'incomplete information' in the sense of (Morris, 1997), which will also ensure noise selection.

Frankel, Morris and Pauzner (2003) also reduce of a two-player, four-action, symmetric game where noise independent selection there is a unique limit as the noise goes to nature of the limit depends on the exact of the noise. (Carlsson 1989) gave a three-example action in which noise independent Cornelli et al. (2004) describe a global of currency crises, where there is a contin-
tinuous trades and a single large trader. This is distribution of the players, and the strategic definition of a single player. They define a strategic equilibrium selected as noise goes to zero as relative informativeness of the large and the consequences. This is thus an application where population selection. However, results are available on games with multiple payoff structures but payoffs are not supermodular and conditional on endogenous decisions. I am better off if I run if few and share in the liquidation of the bank's major paper of Goldstein and Pauzner shows own equilibrium uniqueness for 'bank run payoffs' – satisfying a single crossing property – with uniform prior and uniform noise. This analysis has been followed in a number of applications. They establish that there is uniqueness equilibrium in threshold strategies and there are non-threshold equilibria. However, their analysis does not address the question of which strategies survive iterated deletion of strictly dominated strategies. (Fukao and Pauzner, 2003) demonstrates the existence of a unique threshold equilibrium can be established more generally under a common signal property on payoffs and a monotone likelihood ratio property on signals (not required for global games analysis with supermodular payoffs); however, these arguments do not rule out the existence of non-monotonic equilibria. Results of van Zandt and Vives (2003) can be used more generally to establish the existence of a unique monotone equilibrium under weaker conditions than supermodularity.

The original analysis of Carlson and van Damme (2003) relaxed the assumption of common knowledge of payoffs in a particular way: they assumed that there was a common prior on payoffs and that each player observes a small conditionally independent signal of payoffs. This is an intuitively small perturbation of the game and this is the perturbation that has been the focus of study in the global games literature. However, when the noise is small one can show that types in the perturbed game are close to common knowledge types in the product topology on the universal type space that is, for each type t in the perturbed game, there is a common knowledge type t' such that t and t' almost agree in their beliefs about payoffs, they almost agree about their beliefs about the opponents' beliefs, and so on up to my finite level. Thus the 'discontinuity' in equilibrium outcomes in global games when noise goes to zero is illustrating the same sensitivity to higher order beliefs of the famous example of Rubinstein (1989). Now we can ask how general is the phenomenon that Rubinstein (1989) and Carlson and van Damme (1993) identified? That is, for which games and actions is it the case that, under common knowledge, the action is part of an equilibrium (and thus survives iterated deletion of strictly dominated strategies) but for a type 'close' to common knowledge of that game, that action is the unique action surviving iterated deletion of strictly dominated strategies. Weinsteins and Yildiz (2007) shows that this is true for every action surviving iterated deletion of strictly dominated strategies in the original game. This observation highlights the fact that the selection of actions in standard global games arise not just because one relies common knowledge, but because it is relaxed in a particular way: the common prior assumption is maintained and outcomes are analysed under that common prior, and the noisy signal technology ensures particular properties of higher-order beliefs, that is, that each player's beliefs about how other players' beliefs differ from his is not too dependent on the level of his beliefs.

3 Applications: public signals and dynamic games Complete information models are often used in applied economic analysis for tractability: the complete information game payoffs capture the essence of the economic problem. Presumably there is not in fact common knowledge of payoffs, but if asymmetries of information are not the focus of the economic analysis, this asymmetry seems harmless. In applications games often have multiple equilibria, and policy analysis – and comparative statics more generally – are hard to carry out in multiple equilibrium models. The global games analysis surveyed above has highlighted how natural relaxations of the common knowledge assumptions often lead to intuitive selections of a unique equilibrium. This suggests these ideas might be useful in applications. Fukao (1994) and Morris and Shin (1995) were two early papers that pursued this agenda. The latter paper – published as Morris and Shin (1998) – was an application to currency crises, where the existing literature builds on a dichotomy between 'fundamentals-driven' models and multiple equilibria or 'sunspot' equilibria views of currency crises. This dichotomy does not make sense in a global games model of currency crises: currency attacks are 'self-fulfilling' – in the sense that speculators are attacking the currency precisely because they expect others to do so – but their expectations of others' behaviour may nonetheless be pinned down by higher order beliefs (see Heinemann, 2000, for an important correction of the equilibrium characterization in Morris and Shin, 1998). Morris and Shin (2000) laid out the methodological case for using global games as a framework for economic applications. Morris and Shin (2003) surveys many early applications to currency crises, bank runs, the design of international institutions and asset pricing, and there have been many more since. Rather than attempt to survey these applications, I will highlight two important methodological issues – public signals and dynamics – that have played an important role in the developing applied literature.

To do this, it is useful to consider an example that has become a workhorse of the applied literature, dubbed the 'regime change' game in a recent paper of Angelozio, Hellwig and Pavan (2007). The example comes from a 1999 working paper on 'Coordination Risk and the Price of Debt' presented as a plenary talk at the 1999 European meetings of the Econometric Society, eventually published as Morris and Shin (2004). A continuum of players must decide whether to invest or not invest. The cost of investing is c. The payoff to investing is one if the proportion investing is at least 1 − δ, 0 otherwise. If there is common knowledge of c and θ is 0.1, there are multiple Nash equilibria of this continuum player complete information game: 'all invest' and 'all not-invest'. But now suppose that θ is normally distributed with mean y and standard deviation σ. Each player in the continuum population observes the mean y which is thus a public signal of θ. But in addition, each player i observes a private signal s_i where the private signals are distributed in the
continuum population with mean $\theta$ and standard deviation $\sigma$ (that is, as in the example at the beginning of this article). Morris and Shin (2004) show that the resulting game of incomplete information has a unique equilibrium if and only if $\sigma \leq \sqrt{2 \pi} r^2$, that is, if private signals are sufficiently accurate relative to the accuracy of public signals. This result is intuitive: we know that if there is common knowledge of $\theta$, there are multiple equilibria. A very small value of $r$ means that the public signal is very accurate and there is almost' common knowledge.

This result makes it possible to conduct comparative statics within a unique equilibrium not only in the uniform prior, no 'public' information, limit but also with non-trivial public information. A distinctive comparative statics that arises is that the unique equilibrium is very sensitive to the public signal $\gamma$, even conditioning on the true state $\theta$ (see Morris and Shin, 2003; 2004; Angelotis and Werning, 2006). This is because, for each player, the public signal $\gamma$ becomes a more accurate prediction of others' behaviour than his private signal, even if they are of equal precision.

But the sensitivity of the uniqueness result to public signals also raises a robustness question. Public information is endogenously generated in economic settings, and thus a question that arises in many dynamic applications of global games in general and the regime change game in particular is when endogenous information generates enough public information to get back multiplicity (Tarsahe, 2003; Dasgupta, 2007; Angelotis, Helwig and Papan, 2006; 2007; Angelotis and Werning, 2006; Helwig, Mukherji and Tsyvinski, 2006). This literature has highlighted the importance of endogenous information revelation and the variety of channels through which such revelation may lead to multiplicity or enhanced uniqueness. In addition, these and other dynamic applications of global games raise many other important methodological issues, such as the interaction between the global game uniqueness logic and 'hedging' -- informational externalities in dynamic settings without payoff complementarities -- and 'signalling' -- biasing choices from static best responses in order to influence opponents' beliefs in the future.  

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See also coordination problems and communication; currency crises; purification; quantal response equilibria.

Bibliography


globalization

'Globalization' is a word that gets both its fans and opponents very agitated. But what exactly is the globalization debate really about?

The answer is that the globalization debate surprisingly large number of issues, including lie outside of economics. A non-exhaustive list derived from a reading of the writings of both n- and non-economists (see a very partial list of references in bibliography) follows:

1. Liberalization versus regulation of international trade, capital movements, and migration.

2. Market imperfections that arise with (ethic and international) goods markets, capital privatization, macroeconomic crises, i property rights, and so on.

3. Evaluation of the performance of the International Monetary Fund (IMF) and the World Bank in particular their policy prescriptions 'Washington Consensus,' 'shock therapy,' 'tropical adjustment'),

4. Effects of foreign trade and capital movements on country workers ('out-sourcing') and on poverty workers ('whatsleys'),

5. Extreme world inequality and poverty,

6. Capitalism ('neoliberalism') versus alternative ideologies.

7. Westernization/Américanization versus local identity.

8. Unequal distribution of political power between West (both Western governments and the rest).

9. Effect of global economic growth on the rest of the world.

10. Western imperialism and military intervention in the rest of the world.

Arguably, the vagueness of a term that includes such separate debates has done a disservice to e political debate, causing many globalization participants to think they disagree with people whom they really agree, e to think they ag...
globalization

Globalization is a word that gets both its proponents and opponents very agitated. But what exactly is it? What is the globalization debate really about?

The answer is that the globalization debate is about a surprisingly large number of issues, including some that lie outside of economics. A non-exhaustive list of issues derived from a reading of the writings of both economists and non-economists (see a very partial list of references in the bibliography) follows:

1. Liberalization versus regulation of international trade, capital movements, and migration.
2. Market imperfections that arise with (either domestic or international) goods markets, capital markets, privatization, macroeconomic crises, intellectual property rights, and so on.
3. Evaluation of the performance of the International Monetary Fund (IMF) and the World Bank, including in particular their policy prescriptions (the 'Washington Consensus', 'shock therapy', or 'structural adjustment').
4. Effects of freer trade and capital movements on rich country workers ('outsourcing') and on poor country workers ('sweatshops').
5. Extreme world inequality and poverty.
6. Capitalism ('neoliberalism') versus alternative systems.
7. Westernization/Americanization versus local culture.
8. Unequal distribution of political power between the West (both Western governments and corporations) and the Rest.
10. Western imperialism and military intervention in the rest of the world.

Arguably, the vagueness of a term that includes at least ten separate debates has done a disservice to economic and political debate, causing many 'globalization' debate participants to think they disagree with people with whom they really agree. It also explains some of the difficulties in communication between economists and non-economists about globalization, because the two groups really have different debates in mind. Economists (including those identified as 'globalization critics') have focused largely on issues 1–5, while the non-economists — though not ignoring 1–5 — seem to have something else in mind itself.

For example, Dani Rodrik (1997) and Joseph Stiglitz (2002), who have both acquired a reputation as globalization critics by focusing mainly on issues 1–3, are embraced eagerly by some globalization protesters whose main issue is really 6: the critique of capitalism (sometimes called 'neoliberalism'). This is not meant as a criticism of Rodrik and Stiglitz; rather, it highlights the confusion that exists when two prominent mainstream economists who are talking about tinkering with and fine-tuning capitalist markets are seen as allies by those who are opposed to free market capitalism.

This article can hardly do justice to the complexity of all of these debates, nor is there much hope of getting everyone to discontinue the almost criminally vague use of the term 'globalization' in debate. The article argues that most of the energy in the debate indeed comes from the clash of attitudes: the enthusiastic and anti-patriotic — towards capitalism and free markets.

This article thus focuses on two key themes about the globalization debate. First, I give some intellectual history of the debate about capitalism (issue 6), which will place in perspective some of today's globalization debate including that by the non-economists. This has the objective of dispelling some of the puzzlement of many economists about the sound and fury surrounding globalization, through realization that it is partly just another manifestation of a long intellectual debate about capitalist free markets, which economists have been engaged in for decades if not centuries. Second, the article tries to place the anarchy towards free markets in a contemporary perspective by discussing whether overly simplistic models and unrealistic promises of quick and sizeable results from 'globalization' for poor countries have further fueled this anarchy. I consider at the same time whether the zeal of the globalizationists may have led them to endorse counterproductive and unrealistic attempts at wholesale social transformation, which generate an even more severe backlash.

Let's start with the long-standing debate about capitalism. Intellectual history makes clear how the gains from trade (in goods, finance, and labour services) under capitalism amount to such a revolutionary idea that economists are often its lone proponents in the wilderness. There are three major habits of thinking that create difficulty in communication between economists and non-economists on gains from trade. One is the mindset that holds that economic interactions are zero-sum games (a partially understandable mindset when capitalists have such skeletons in the closet as military conquest,