European Credit Views

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A Nash equilibrium for the euro

Insights from Game Theory on the fate of the euro zone

It's all about incentives

In *A Nash equilibrium for Greece*, we established the idea of using Game Theory for analysing the Greek PSI programme. In this note, we extend the concept to the broader euro zone debt crisis in order to explain its dynamics and likely future path.

The continued existence of the euro will hugely depend on the incentive structure of its members to defend it. In order to do so, costs must be appreciated and allocated. We therefore demonstrate how:

- Incentives to deal with these costs are aligned only under certain conditions;
- An imbalance of incentives could lead to a euro breakup;
- Incentives evolve through time and interventions;
- Brinkmanship and threats are used as tools to improve either party's outcome;
- Market stress is a logical and intended consequence; and
- Markets can be used as a mediator to improve each player's outcome

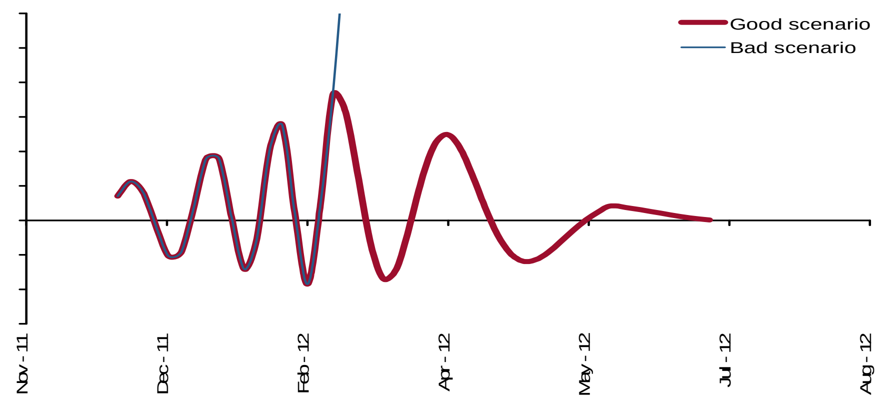
Based on this Game Theory analysis, we see two scenarios for the future of the euro:

1) A (catastrophic) breakup or (very expensive, probably catastrophic) exit of at least one large member. We think this is possible but not likely. We estimate the probability to be 10%-20%.

2) A long, painful and volatile continuation of the crisis that can only be slowly improved by some type of inter European enforceable contract.

Exhibit 1: Schematic future of the euro crisis

The timeline on the x-axis is for illustrative purposes only. The y-axis measures stress.



Source: Credit Suisse

Why Game Theory: It's all about incentives!

In order to understand the European debt crisis, it is of crucial importance to understand its drivers and dynamics. Without this understanding, predictions about its future developments – short- or long-term – are not only extremely difficult, but virtually impossible to make.

The very nature of the European debt crisis is that it is hugely driven by players whose decisions are made in a way that protects their own interests – if not to say optimizes their position – while understanding that any action by itself will have a direct impact on any other party's outcome and therefore will likely trigger a reaction. Assessing this likely reaction is of paramount importance when deciding on one's own actions in order for the long-term relationship between counties not to be damaged. Therefore, the euro crisis is **all about incentives**, and how these incentives of the participating countries, central banks, investors, international institutions, etc. are interlinked.

One of the central observations the current publication is based upon is that these incentives are not always aligned. It, therefore, is crucially important to understand under what conditions they are aligned, how incentives of players can be changed by other players and how incentives evolve over time.

This is the ideal situation to be described by Game Theory. The mathematical subject of Game Theory involves players, strategies they can choose from, and pay-off functions that evaluate the outcomes for each player. Game Theory is not only able to analyse a situation that is as complex as the euro crisis, it also is capable of making predictions about likely outcomes if all players act rationally.

We previously used the concept of Game Theory to analyse the Greek PSI in the so called "participation game " in *A Nash equilibrium for Greece*. In this more holistic approach to the euro zone debt crisis, the game is different and we will use several of the results of Robert J. Aumann and Thomas C. Schelling, who won the Sveriges Riksbank Prize of Economic Sciences in Memory of Alfred Nobel in 2005, "for having enhanced our understanding of conflict and cooperation through game theory analysis."

Description of the Game

There are various ways one can define the European debt crisis: what exactly is being negotiated, what the role of each player is and what the exact strategies are that each player can embark on? In this note, we step back from the inane frequency of news items for one moment and try to describe the crisis in the most simplistic and basic manner. Essentially, the crisis is about how the costs of the euro can be allocated to the beneficiaries and ultimately what share of these costs everyone has to bear?

We could now go into more details about the sometimes subtle differences among players – for example, does the German political elite have exactly the same incentives as its corporates, financials or even individuals, or do all the core countries have the same incentives, etc. – but that would unnecessarily overcomplicate the game set-up. We rather restrict ourselves to two players, a type of fiscal hawk on the once side, most easily associated with a core or northern European country (or the ECB for that matter) and on the other, some sort of fiscal dove, for these purposes most readily assigned to a peripheral country. These country associations are only made in order to initially find access to our way of thinking. These are generalizations, as every sovereign in fact is some sort of mix of the two players, which becomes apparent when trying to categorise France on the one hand or on the other, appreciating the heterogeneity of each country as alluded to above.

A key point to take away though, is that the core player wants to impose as large a portion of the costs for the euro on the periphery by demanding more austerity while the periphery player wants to allocate the costs away from itself, i.e., in the core.

This cost arises in our view as an offset to the (larger) past and future benefits of the euro. But the past benefits have been recognised while the past costs have been under-recognised, in our view, creating the condition that is driving the current problems. See, for example, our basic cost estimates in *European Credit Flash: Stress!*

How costs can be allocated

There are varied ways that costs could materialize. To mention just a few: inflation, bank rescues and wind-downs and debt mutualisation. The first would likely impose losses on the savers, particularly pensioners in the core as, if and when the ECB cuts rates further and embarks on QE. Costs via the banking sector could materialize if more peripheral debt losses would be imposed on the banks, which in turn would bring costs to the core via bank guarantees, recapitalizations or even a reduction in lending activity to corporates and households. Even a bank failure could be possible. Finally, debt mutualisation, for example, via some sort of Eurobond, would impose costs on the core via higher borrowing rates.

The main method of enacting cost allocation to the periphery is via increased austerity and labor market reforms. Most common examples include higher taxes, lower social benefits and pension age increases.

Problem: the costs are rising

As long as neither of the two players is accepting the costs sufficiently and credibly, the market is becoming increasingly suspicious as to where these costs will materialize with the result that it allocates these in the most painful way. As we have described in *Trading correlation in the euro CDO*, implied correlations are increasing, meaning that the market is allocating the costs in ever more senior tranches, i.e., core European countries. This process is accelerating with the result that in the week of 16 November 2011, the senior tranche, i.e., all AAA rated sovereigns, disproportionally sold off in comparison to the more junior tranches. This process hasn't stopped but rather has become more extreme with German government bonds one week later falling in a general market sell-off, meaning that they traded as a credit for the first time in recent memory. The market thus seems to be pricing in the ultimate level of systemic risk.

Game of Chicken: single step

The idea of the game of chicken, also known as the hawk-dove game, is that while each player prefers not to yield to the other, the worst possible outcome occurs when both players do not yield. Its name comes from a game in which two players drive towards each other, where the player that swerves first loses and is called a chicken, while the other player wins. If neither player swerves, they collide, and this crash outcome is clearly the worst outcome for both players.

In this setup, the game has three equilibria: two pure and one mixed strategy equilibrium. The pure are comprised of exactly one player swerving and one going straight. In the mixed strategy equilibrium, each player chooses to go straight with a certain probability, therefore making a crash possible.

The pure equilibria are plausible in situations where the two drivers are able to coordinate on either equilibrium. Changing the symmetry of the payoffs in the game can lead both players to expect hawkish behaviour by the player who has the most to gain from it, thus rendering that equilibrium "salient" or "focal."

Exhibit 2: Game of chicken

Row player's pay-off listed first in each cell and **a>b>c>0**

	Straight	Swerve
Straight	0,0	a,c
Swerve	c,a	b,b

Source: Credit Suisse

In some conflict situations, the equivalent of a crash is less undesirable than the humiliation that may be associated with swerving when the other player continues straight. In such situations, the payoff from losing is negative, i.e. , a > b > **0 > c**, and the game becomes a prisoner's dilemma, with both players not swerving as the ultimate outcome.

Breakup probability low if incentives across players are symmetric

In the current situation, every nation has an incentive to impose the costs of the euro as much as possible on the other partners, while making sure that the euro project does not fail. Since, in the current situation, a euro breakup would be disastrous for all parties involved, the game we are dealing with is a game of chicken rather than a prisoner's dilemma.

Furthermore, It also is not a zero sum game; the cost must be borne by someone, but pure periphery cost acknowledgement is not sufficient. The core must acknowledge the costs, too.

We start by looking at this from a single step (i.e., not repeat game), non evolving (i.e., the payoff functions stay constant) and symmetric setup, which we will gradually make more realistic in successive sections.

In this setup, a player wins if he/she imposes as much of the costs of the euro on the other party, while contributing as little as possible him/herself. Since the game is symmetric, being at the losing end of this negotiation clearly is less beneficial, here expressed by the fact that a>c. Furthermore, we are positive that a euro breakup, in the current more or less symmetric situation (in game theoretic terms: balance of payoffs) would be the worst outcome for both parties. For the sake of time and space, we do not go into detail why each of the 17 members of the euro region shares this incentive in the current situation, but refer to the appendix where we list the motives of some players. The fourth state, the tie, where costs are shared by both parties, is deemed worse than a win, but better than a loss and particularly better than a crash, e.g., euro breakup or exit.

Exhibit 3: Euro crisis: single step, non-evolving and symmetric game

The row player is the core; the column player the periphery

	No more austerity	More austerity
No cost sharing	0,0	a,c
Cost sharing	c,a	b,b

Source: Credit Suisse

As in the original chicken game above, there are two pure Nash equilibria:

1) "cost sharing" by the core and "no more austerity" by the periphery; and

2) "no cost sharing" by the core and "more austerity" by the periphery.

And a third, mixed strategy Nash equilibrium, which seems more plausible in a game without any commonly understood coordination principle. The "core" player in this case is uncertain about the "periphery" player's move, estimating the probability of it to implement no further austerity to be p, and vice versa. The Nash equilibrium probability of choosing the hard[1] strategy therefore is p = (a-b)/(a-b+c)[2], which leaves each country indifferent to chose the hard or soft strategy. The probability of a euro breakup therefore is $p \times p = p^2$ [3]. As a consequence, the probability of such a breakup decreases as the loser's payoff increases. In order to minimise this probability, the goal must hence not only be to contain the winner's gain, but equally importantly to improve the loser's payoff.

In the below table, we choose some numbers for the payoffs that reflect the adversity of a breakup scenario. (The payoffs of all other outcomes are by a large margin higher than 0, which represents the breakup outcome.) The result is that in the mixed strategy equilibrium, each player chooses the hard option with probability 28.6%, assigning a probability of 8.2% on a euro breakup.

Exhibit 4: Euro crisis: Example payoffs

	No more austerity	More austerity
No cost sharing	0,0	10,5
Cost sharing	5,10	8,8

Source: Credit Suisse

Asymmetric interests generate breakup risks

Key to the three equilibria is that the game is symmetric. If it is not, it will impact the result. The so called evolutionarily stable strategy (ESS), which is a refined type of Nash equilibrium, that, once it is fixed in a population cannot be "invaded" by alternative new strategies, plays an important role in this.

In order for row players to choose one strategy and column players the other, there must be a way for each to know which role (column or row player) they are playing. If the game is symmetric, then both players must choose the same strategy, and the ESS will be the mixing Nash equilibrium. If the game is asymmetric, then the mixing Nash is not an ESS, but the two pure – depending on the role – Nash equilibria will be.

The below table highlights how dangerous an asymmetric game could be for the euro. The payoffs for the core player are unchanged, however, the payoffs from winning (i.e., the core solely bearing the costs) has increased while the payoff for losing or a tie have decreased. As a result, the mixed strategy equilibrium probability of the peripheral player choosing to play "hard" would increase from 28% to 60%, making the probability of a breakup more than double as likely[4]. We could imagine such a situation arising if the core forced the periphery into ever harsher austerity measures that will not be reciprocated via some cost acknowledgment by the core.

An (increasing) imbalance between the benefits of staying in the euro is hence one of the most dangerous situations, and needs to be avoided.

Exhibit 5: Asymmetric game

	No more austerity	More austerity
No cost sharing	(0,0)	(10,4)
Cost sharing	(5,12)	(8,6)

Source: Credit Suisse

[1] From here, we will refer to the core choosing to share costs and the periphery to implement more austerity by choosing the "soft" and otherwise the "hard" option.

[2] The hard option generates a payoff (1 - p)a, while the soft option yields pc + (1 - p)b. Equating the two determines the equilibrium probability.

[3] Where the assumption is made that the euro breaks up if both parties choose a hard strategy and that it continues in its current form if at least one player chooses a soft strategy.

[4] The probability of the bad outcome would increase from originally 8.2% to 17.1%.

Brinkmanship and threats as tactics to improve one's situation

Brinkmanship is a tactic by one player that is intended to minimise the possibility of the other player choosing an aggressive strategy. The idea here is that a player can make a threat of irrational behaviour namely to counter the aggressive strategy by the opposing player with one's own aggressive choice. For this tactic to work, the necessary condition is that the threat is **credible**.

The reaction from Chancellor Merkel and President Sarkozy to the former Greek PM's plan for a referendum to decide if Greece should agree to the second EU bailout plan was a classic example of brinkmanship. In our opinion, their stipulation to let the Greek people not decide whether they agree with the bail-out plan but rather if they want to stay in the euro, was a threat of irrational behaviour. Now they have at least opened the possibility of Greece leaving the euro, which currently would be a worse option for the remaining countries in the euro. The fact that this threat was credible enough – Greece already had a last chance when the Troika left Athens due to a lack of sufficient progress in the run-up to the previous tranche payment and only came back after Greece acknowledged this – was sufficient for Papandreou's allies to abandon him, with the well known result of a new government and a called-off referendum.

We think that the extended rhetoric of the German and French leaders with regards to treaty changes that would allow a country to leave the euro without making an EU exit mandatory, fall into the same category of brinkmanship, since preparing the grounds for such a discussion in advance makes the eventual threat ever more credible. If acting this way is to be successful, it will also depend on the symmetry of the game at the next stage, as a significant imbalance in cost attribution to the core and periphery could make even a credible threat harmless.

For any player, it is key to evidently choose the hard option rather than just threatening to do so. The ECB is pre-committed to the euro. Any threats from this side are therefore not really credible, in our opinion.

However, as tempting as these bargaining tactics may seem, if both players did use them by making irreversible and incompatible commitments, a euro breakup may be the result.

Balance of Terror by pre-commitment:

Suppose the core could pre-commit to no more cost sharing if the periphery did not impose further austerity measures. More precisely: First the core chooses whether to share costs or to rule out cost sharing if and only if the periphery did not implement further austerity measures. Thereafter, the periphery observes the core's move and decides whether or not to add further austerity. If payoffs are as described in Exhibit 3, the (subgame perfect) equilibrium outcome will be that the core threatens to not share the costs, and both countries refrain from their hard strategy. Indeed, it is sufficient that either country commits to its hard strategy with a sufficiently high probability[5] .This type of deterrence tactics could help for the worst outcome to be prevented - a balance of terror.

Suppose, moreover, that country 1 is uncertain whether country 2 actually prefers a euro exit/break-up to the negotiated outcome. In the terms of game theory, that means that country 1 now has incomplete information about country 2's payoffs. Does it still make sense for country 1 to commit to a hard strategy if country 2 chooses to do so? According to Schelling's analysis the optimal commitment strategy is then often to choose a probability of opting for the hard strategy that is less than one. In other words, if faced with a player who is escalating the situation, the other player should threaten to let it "slip out of hand" rather than commit to certain retaliation, or how Schelling said, make "threats that

[5] Let us assume Country 1 can commit to retaliate with any probability pi element of [0, 1] if Country 2 did play "hard". If the payoffs of Country 2 are as defined in Exhibit 3, the requirement for successful deterrence is that b>= (1 - pi)a or, equivalently, that pi >= 1 – b/a = pi*.

leave some things to chance." The reason is that a modest probability of a euro breakup may be enough to deter the other player's hard strategy[6]. In our opinion, this is exactly what has been intended by some European governments so far. Unfortunately, both sides seem to understand game theory very well, meaning that threatening to call the other one's bluff has increased the pressure ever more.

Taking turns can help

One constructive way of dealing with the crisis could be to take turns in deciding whether or not to acknowledge further costs by each country. The idea behind this is that, if the solution of cost attribution can be done gradually, each player can threaten to stop this incremental process at any time, thereby incentivising the other player to also commit to a share of the cost. Simply put, some sort of 'tit for tat'. The central positive scenario therefore seems to be one in which ideally a contract between all or a majority of euro member states is signed, under which each country (not only the periphery) commits to a more prudent fiscal policy and in return, each time a certain milestone, for example a constitutional debt brake, has been achieved, another step towards debt mutualisation (or other way of imposing costs on the core) will be permitted. Maybe prolonging the "solution to the crisis" is therefore part of the solution.

One of the conditions of such a strategy to work is that discount factors are either one or close to one. The problem with the euro crisis is that for each party it is cheaper to commit to certain costs in the future rather than imposing them immediately. In addition, discount factors, particularly credit risky ones in the periphery, are currently very low. It therefore is not quite clear if this strategy can work.

Evolution of the game

One of the key characteristics of the current crisis in Europe is that it is not a one stage game, but rather an ever repeating one that has been dragging on for nearly two years. An important corollary from this is that countries take into account the relationship they hold with the other countries and how their actions will impact these relationships in the future. To make a drastic example, all countries will hugely appreciate the fact that there has not been a war on western European soil for nearly 70 years, resulting in a preferred behavior that will not damage their international relationships too far.

Crucially, it also is a game that evolves over time, since for example after a couple of rounds of successful austerity measures and fiscal reforms, the core would be more willing to bear a larger share of the costs, in our opinion. Simultaneously, the periphery would become ever more austerity fatigued such that the relative cost of a euro breakup would become less punitive to it. So, while the crisis might have been symmetric at some stage of the game, one important feature any model needs to reflect is that it is evolving in time and payoff functions.

Stress, for example, has an important impact on the evolution of the crisis. The higher government bond yields are trading and the more difficult it becomes as a result for sovereigns to issue new bonds to finance the running of their state, the more willing they should be to make concessions in order to strike a deal.

This stress is a result of the aforementioned brinkmanship and credible threats, that are intended to force the other player into a soft strategy. The ECB's tactic of not committing to buy peripheral government bonds in size is a classic example of how stress is used for this purpose. The central bank intentionally keeps the stress at high levels, knowing that it is

[6] Let theta be the probability that Country 1 assigns to the possibility that Country 2 prefers to play hardball regardless of the retaliation threat. As shown above, for pi < pi*, Country 2 will still prefer a hard strategy for sure, so the payoff to Country 1 is then (1 - pi) c, a decreasing function of pi. For pi >=pi* its expected payoff is theta(1 - pi)c + (1 - theta)b, again a decreasing function of pi. Thus, it is optimal for Country 1 to choose to deter (choosing p = pi) if and only if theta(1 – pi*)c + (1 - theta)b is at least as large as the payoff c from not retaliating (pi = 0), or, equivalently, if and only if theta <= (1 – c/b)/(1 - c/a).

necessary for European governments to act and converge to tighter and more coordinated fiscal policies. This clearly is in the core's interest as evidenced by Merkel's comments that encouraged this type of behaviour by the ECB. However, the periphery is also using the tool of stress, knowing that for example, an eventual inability of Italy to refinance its debt on the primary market and the threat of an Italian default could potentially force the core into last minute intervention. In such a make or break scenario, we would assume that the core would prefer a last minute bailout to the alternative of a Italian default, which could result in disastrous implications for the European banking system and economy, particularly in the core. It thus becomes very clear why European debt and financial markets are in such a high degree of distress and illiquidity. The reason is that both parties are using it as a means of trying to make the other player react first. The inherent problem with this is that an actual bad outcome, for example, a euro exit or breakup is not entirely unimaginable anymore and unfortunately becomes a real risk.

Multi-step and stress dependent game

In the subsequent sections, we will model the following three features:

- Multi-step nature of the game;
- Its time evolution; and
- Stress dependency.

We do so, by establishing a scenario dependent game whose stages are a function of stress. In each scenario, the payoff functions of the two players are different due to a new level of stress. We start with the original game as shown in Exhibit 4 and label this the "very high" stress level stage game. Next, we add three stages in which the stress is "little", "medium" and "high". These can be achieved from higher stress levels by at least one player choosing a soft option. Finally, we add one more stage of the game in which the stress level is "extreme." This would be achieved by both players continuing with an aggressive strategy while making implicit and/or explicit threats and exhibiting a typical brinkmanship behavior with the result of escalating stress. These various stress levels and the respective payoff functions are shown in Exhibit 6. The numbers we chose are admittedly subjective, however, we chose them based on the following principles: As stress increases, the payoff difference between:

- Losing (payoff c) and a worst outcome (both choose to play aggressively) should increase. In other words, the higher the stress, the worse a bad outcome will be relative to the second worst scenario.
- A tie (both parties choose the soft strategy, payoff b) and a worst outcome should increase. Again, the higher the stress, the worse a bad outcome will be relative to a tie.
- Winning and a tie should decrease. This means, that the higher the stress becomes, the less important it becomes to win.

In the lowest stress stage, we actually assume that $c<0$, which makes this stage of the game a classic prisoner's dilemma, with only one pure Nash equilibrium, namely an aggressive strategy from both players. This outcome will result in a step-up in the stress ladder to the "medium" stress level. As we highlighted in A Nash equilibrium for Greece, in a multi step game, this suboptimal outcome doesn't have to materialise at every instance. In fact, communication and past experience of this undesirable outcome as a result of non-cooperative behavior can temporarily lead to the pareto optimal outcome of both parties choosing the "soft" option. However, at the moment, we clearly are not at this stage, meaning that previously both players have chosen the "hard" option. Furthermore, it remains to be seen if they will act differently if this "little" stress stage is ever attained again.

Exhibit 6: Multi-step and stress dependent game

The higher the stress, the higher the payoffs for losing (c) and a tie (b) and the lower the difference between winning and a tie (a-b). The lowest stress scenario is a prisoner's dilemma, while all other stages are of the chicken type.

Stage 5: extreme stress

	No more austerity	More austerity
No cost sharing	(0,0)	(10,8.5)
Cost sharing	(8.5,10)	(9,9)

Stage 4: very high stress

	No more austerity	More austerity
No cost sharing	(0,0)	(10,5)
Cost sharing	(5,10)	(8,8)

Stage 3: high stress

	No more austerity	More austerity
No cost sharing	(0,0)	(10,4)
Cost sharing	(4,10)	(6,6)

Stage 2: medium stress

	No more austerity	More austerity
No cost sharing	(0,0)	(10,2)
Cost sharing	(2,10)	(4,4)

Stage 1: little stress

	No more austerity	More austerity
No cost sharing	(0,0)	(10,-1)
Cost sharing	(-1,10)	(2,2)

Source: Credit Suisse

Importantly, we think that the worst outcome from each stage is different, meaning that while a worst outcome in a low stress stage will most likely mean that the game advances into the next higher stress level; a worst outcome in the "extreme" stress stage will likely lead to a catastrophic outcome such as a euro breakup.

Another conclusion we can draw from this is that with increasing stress level, the probability p of each player choosing the aggressive strategy at each stage decreases and hence the probability of a worst outcome p^2 (we still assume a symmetric game) also decreases. Based on the above stress levels, we highlight their respective probabilities p and p^2 in Exhibit 7.

Exhibit 7: Probability of aggressive behaviour

Scenario	Probability p	Probability p squared
Stage 5: extreme stress	11%	1%
Stage 4: very high stress	29%	8%
Stage 3: high stress	50%	25%
Stage 2: medium stress	75%	56%
Stage 1: little stress	100%	100%

Source: Credit Suisse

Correlated equilibrium: Let the market be your friend

The game theoretic concept of a correlated equilibrium is a generalization of the better known Nash equilibrium and was first treated by mathematician Robert Aumann. In a correlated game, each player chooses their action as a response to observing the same public signal. A player's strategy assigns an action to every possible signal a player can observe. If no player wants to deviate from his/her chosen strategy (assuming the others don't deviate), it is called a correlated equilibrium. In other words, as for the Nash equilibrium, a strategy is a correlated equilibrium if no player can improve his/her expected outcome by altering his/her strategy selection.

Example: the game of chicken

If we start with the initial game of chicken for the euro crisis as in Exhibit 4 and add a third party that randomly selects one of three signals (soft, soft), (hard, soft) or (soft, hard) from a uniform distribution (i.e., each with probability 1/3), where soft means that the mediator tells the periphery to implement further austerity measures while if shown to the core it signals to bear more costs (if hard is shown, it obviously signals the opposite). The key behind this is that players are only shown their own part of a strategy pair, i.e., they wont see what the other player has been assigned, but the probability distribution of what the other player has been shown will differ depending on one's own signal.

For example, if the first player is shown a "hard" signal, then he/she would know that the other player must have been shown a "soft", meaning that if the other player doesn't deviate from his/her assigned strategy, it is better for the first player to follow the recommended strategy and play "hard" (payoff 10 rather than 8). The other possibility is that the first player sees a "soft" signal. In this case, the player has no information about whether the other player has been recommended to play a "soft" or "hard" strategy. Again, assuming the other player follows his/her assigned strategy, the probability that he/she will play "soft" or "hard" is ½ (the probability of the other player seeing either signal is 1/3, but conditionally on the first player seeing a "soft" is 1/3 divided by (1-1/3)=1/2. As a result, the (conditional) expected payoff for the first player is (10 + 0)* ½=5 when playing "hard" and (8 + 5) *1/2=6.5 when choosing "soft". Hence it is preferential for the first player to chose "soft" and therefore to follow the strategy: "Comply with the signal" if the other player does so, too. Since the game is symmetric, the other player is in the same situation and the strategy to follow the signal is a correlated equilibrium.

Since there are three types of signals that can be shown to a player, each happening with a probability of 1/3, the (unconditional) expected payoff for each player is 10* 1/3 + 8* 1/3 + 5* 1/3 = 7.67. Interestingly, this is higher than the expected payoff from the mixed strategy in the original non-mediated game, which was 7.14. In other words, listening to the mediator improves the situation of both players versus the original mixed strategy equilibrium. Remarkably, even in the game with the five stages of stress, the expected payoff from a game with these signals is higher than the one from the mixed strategy (or the pure Nash equilibrium in the "little" stress stage) in a uncorrelated game.

Furthermore, as shown in the below table, the absolute and relative difference between the equilibria in the mediated and non-mediated games both decrease the higher the stress becomes.

Exhibit 8: Expected payoff comparison

	p	a	b	c	p(1-p)*a	(1-p)*(1-p)*b	(1-p)*p*c	Expected payoff from mixed strategy	Expected payoff from mediated game	Difference	Difference (%)
Stage 5: extreme stress	11%	10	9	8.5	0.94	7.20	0.80	8.95	9.17	0.22	2%
Stage 4: high stress	29%	10	8	5	2.04	4.08	1.02	7.14	7.67	0.52	7%
Stage 3: Medium stress	50%	10	6	4	2.50	1.50	1.00	5.00	6.67	1.67	33%
Stage 2: little stress	75%	10	4	2	1.88	0.25	0.38	2.50	5.33	2.83	113%
Stage 1: Very little stress	100%	10	2	-1	-	-	-	-	3.67	3.67	NA

Source: Credit Suisse

However, in the case of the "medium" stress scenario, the strategy of following the recommended signal is not a correlated equilibrium. It would be dominated by a strategy in which each player chose to play "hard" regardless of what they have been shown. For the strategy of following the signal to become a correlated equilibrium again, the probabilities for the ("soft", "hard") and ("hard", "soft") signals need to be increased from 1/3 to at least 43%.

To be precise, if the probability of exactly one player being shown a "soft" signal is 43%, then the conditional probability of the other player being told to play "soft" under the condition of having seen a "soft" signal oneself is (1-2*43%)/(1-43%)=0.25. Therefore, if shown to play "soft", the expected payoff for the first player is (10 *0.25 + 0*0.75) =2.5 when playing "hard" and (4*0.25 + 2 *0.75)=2.5 when choosing soft, i.e.. the player will not prefer either option. Since he/she still prefers to play "hard" when instructed, the strategy of following the signals becomes an equilibrium again. This can be generalized further: The strategy to follow the signal is a correlated equilibrium if the probability of a "soft" signal for each single player is pi and the probability both are shown a "soft" is (1-2*pi), where pi must be greater than $(a-b)/(2a-2b+c)$.

More realistic market signal probabilities

In reality, the probability of the market not giving any signal, or in fact, being interpreted to have not shown a signal, has to be greater than zero. Furthermore, the interpretation of the market by one player cannot be completely uncorrelated to the other player's perception, since market prices are publicly observable and commented on.

We therefore use a simple correlated latent variable model in which each player i (i=1,2) interprets the market to have given a signal to play "soft" if a certain threshold c_i has not been exceeded by each player's respective perception of the market r_i, which itself is driven by market prices Y and an idiosyncratic variable ε_i that adds some subjectivity to the objective market price observation. Mathematically speaking:

$$r_i = \sqrt{\rho}Y + \sqrt{(1-\rho)} + \varepsilon_i$$

Where, ε_1 , ε_2 and Y are all mutually independent and follow a standard normal distribution. It follows that r_i i=1,2 both are standard normal distributed random variables, whose correlation is ρ , i.e., their joint distribution is bivariate normal with correlation parameter ρ .

Let us continue to assume a symmetric game with each player being shown a signal to play "soft" with probability q. It can be shown that $c_i = N^{-1}(q)$ [7]. The following probabilities can then be calculated using a bivariate normal distribution N_2:

- P(neither player is shown a "soft" signal)= $N_2(-c_1, -c_2, \rho)$ [8]
- P(Only player 1 is shown a "soft" signal)= $N_2(c_1, -c_2, -\rho)$
- P(Only player 2 is shown a "soft" signal)= $N_2(-c_1, c_2, -\rho)$
- P(Both players are shown a "soft" signal)= $N_2(c_1, c_2, \rho)$

While we think that a higher stress level will increase the probability q of a player being shown a "soft" signal, there are two cases to consider:

1) Positive and rising correlation as a function of stress; and
2) Negative correlation

The former seems initially to be the more intuitive. Both players observe the same market and their interpretation of its endogenous stress level should be more or less aligned. In other words, we would find it difficult to imagine that one player thinks the market represents a very high stress level, while the other disagrees entirely and considers it a "little" stress level. We would also think that with increasing stress, the degree of disagreement should decrease, meaning that correlations should increase.

The numbers in Exhibit 9 are examples of such a calibration. When we apply these to the various stress levels, we find that the strategy to follow the signal from the market is not a correlated equilibrium anymore. While it still would make sense for a player to follow a "soft" signal (assuming the other player followed his/her signal as well), the best strategy following a "hard" signal is no longer to play "hard", making the assumption about the other player to follow his/her signal flawed.

Exhibit 9: Positive and rising correlation between signals

The probability q is the probability of a "soft" signal being shown to a player. The probability of exactly one player receiving such a "soft" signal is the probability of one player receiving a short signal and the other player not.

Scenario	q	rho	Exactly 1 signal	no signal	2 signals
Stage 5: extreme stress	80%	60.0%	20.2%	9.9%	69.9%
Stage 4: very high stress	60%	40.0%	35.6%	22.2%	42.2%
Stage 3: high stress	40%	20.0%	42.0%	39.0%	19.0%
Stage 2: medium stress	25%	0.0%	37.5%	56.3%	6.3%
Stage 1: little stress	5%	-20.0%	9.8%	90.1%	0.1%

Source: Credit Suisse

Our interpretation of this is that in a high stress environment that is recognized by each player, there is little added value in following the markets signals, due to the already strong incentive to play "soft" (expressed by the payoffs a, b and c all being high relative to the ("hard", "hard") strategy's payoff of zero). That is not to say that the market does not convey any valuable information. In fact ,it probably is an important reason for a player to recognize the stage of stress they are in.

However, the second environment with negative correlations, as for example shown in Exhibit 10, actually constitutes a correlated equilibrium. In this case, both players are incentivised to follow their interpretation of the market. The reason for this is that the negative correlation increases the probability of outcomes in which only one player interprets the market to be giving a "soft" signal. The three-card game explained above in

[7] where N() is the univariate, standard normal distribution function

[8] This is the joint probability of both random variables r1 and r2 being lower than their respective thresholds c1 and c2.

fact is an extreme case of negative correlation, in which the probability q of a “soft” signal for each player is 66.67% and the correlation ρ is -1. One can show that for sufficiently negative correlation, the strategy to follow the market is not only a correlated Nash, but also an equilibrium in which the expected payoff for each player exceeds the one from the (uncorrelated) mixed strategy. Hence, it would improve both players’ situation to “listen to the market.”

Exhibit 10: Negative correlation between signals

The probability q is the probability of a “soft” signal being shown to a player. The probability of exactly one player receiving such a “soft” signal is the probability of one player receiving a short signal and the other player not.

Scenario	q	rho	Exactly 1 signal	no signal	2 signals
Stage 5: extreme stress	80%	-60.0%	39.1%	0.4%	60.4%
Stage 4: very high stress	60%	60.0%	66.6%	6.6%	26.7%
Stage 3: high stress	40%	-60.0%	66.6%	26.7%	6.7%
Stage 2: medium stress	25%	-60.0%	47.8%	51.1%	1.1%
Stage 1: little stress	0%	-60.0%	0.0%	100.0%	0.0%

Source: Credit Suisse

A possible interpretation of such a negative correlation scenario is that with increasing stress the symmetry of the game will change, meaning that a player will “intentionally” interpret the markets stress level in a different way[9] than the other player due to the fact that both know that one of them has more to gain or lose from a “soft” strategy than the other[10].

It is possible that these negative correlations exist in reality. We actually think that the periphery has more to lose from choosing a “soft” strategy in a “medium” to “high” stress stage, whereas the same is true for the core in an extreme stress scenario. One reason for this is that if pushed to the very edge, the periphery will probably see less of a difference between not being able to issue new bonds and actually defaulting on its debt, maybe even via an exit from the euro, than the core. Italy for example has a primary budget surplus, meaning it could actually keep running its state financed through tax receipts (however that assumes that tax receipts could continue at current levels even after a default, which we doubt). Germany’s loss from an Italian default on the other hand would probably be worse than a last minute bailout.

Conclusion

Having applied game theory to the problem at hand, our interpretation is that the longer the euro crisis is taking, the bigger the measures will have to be in order to reduce the stress level. Time is money and so the more time that elapses without any sufficient commitment from either side, the further the situation will drift up the stress level scale. Furthermore, every time an agreement is achieved (first and second Greek bailout package; announcement, increase and leverage of EFSF; announcement and increase of PSI etc), if it is promoted to be the big solution to the crisis but either is lacking detail, takes too much time to be implemented or doesn’t actually allocate costs but rather postpones them, then the immediate stress reduction is shortly followed by a gradual stress build-up. The result of this is that the frequency and scale of this oscillation is increasing, i.e., the time it takes to go up in stress levels is becoming shorter and the magnitude of the highest stress level in each cycle increases.

9 In order to demonstrate the impact of correlation, we provide a table of probabilities of each player seeing a signal, conditional on the other player having observed one in the appendix

10 As discussed, this could also be modelled via asymmetric payoff functions or different individual probabilities of being shown a signal.

The reason for this, is the incentive structure of the institutions involved. As long as the highest stress level has not been reached, personal (e.g., Papandreou, Berlusconi), domestic party political (e.g., PASOK vs. New Democracy in Greece) and national (e.g., Italy vs. Germany), interests are not aligned. The only factor that so far seems to have prevented the whole system from collapse is that the market is assuming that the ECB will step in at the final stage and buy government bonds to avert the worst. There are some problems we foresee with this approach:

- There is a risk the ECB misses the point of no return.
- The market doesn't know when that point has come.
- The ECB has no incentive to end the crisis by buying government bonds, as it fears that will increase the moral hazard problem and lead to inflation in the shorter or longer run.

This seems to explain the way the ECB currently acts. It buys government bonds through its SMP program whenever the stress in these increases to new highs, but it also tirelessly highlights that the only solution to the crisis can only be bold moves by European governments and not monetary policy.

We therefore expect the ECB and the European governments to continue preventing the worst outcome; however, we see no incentive for any involved party to stop this cycle through the stress levels.

We see two scenarios in the future:

1) A (catastrophic) breakup or (very expensive, probably catastrophic) exit of at least one large member .We think this has the probability of $p_1 \times p_2$, i.e., the probability of both players choosing an aggressive strategy in an extreme stress scenario multiplied by the number of times this extreme stress level will be reached. At the moment, we estimate this to be between 10% and 20% depending on the degree of asymmetry. As a corollary, we note that the longer the crisis takes, the more likely a breakup becomes.

2) A long, painful and volatile continuation of the crisis that can only be slowly improved by some type of contract that spells out what milestones need to be met over time in terms of

   - deficit (e.g., golden rule a la German debt brake);
   - debt load reductions;
   - improved competitiveness; and
   - economic convergence, etc.

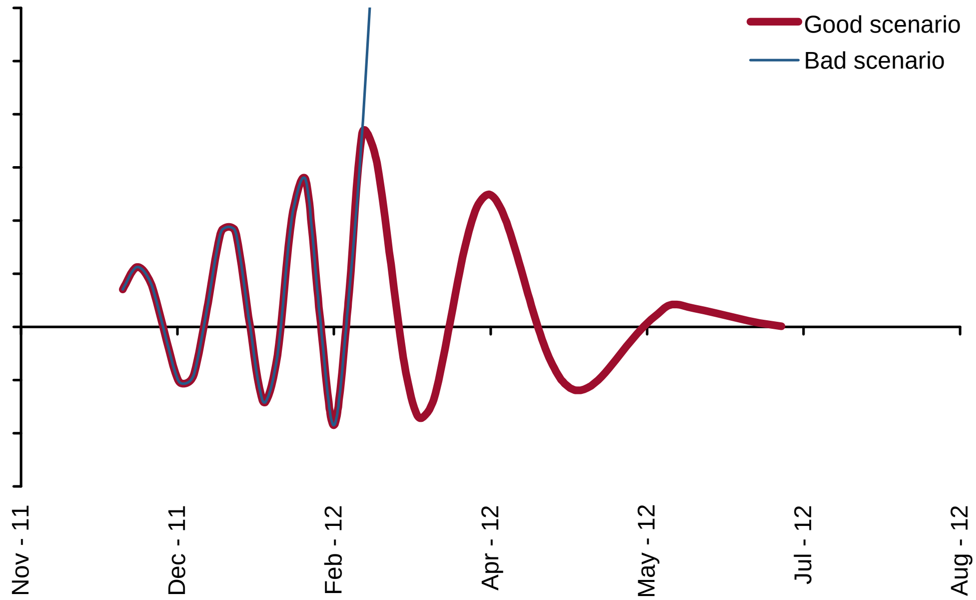
   that will lead onto a path that will still oscillate – since it will not be an immediate solution – but the oscillation will be lower in magnitude and frequency and with a negative drift in terms of stress. We therefore look for signs that such a contract11 is on its way in the near future.

The test for its success will be if real costs will be allocated to both sides in a detailed and balanced way. It needs to be balanced and fair in order to keep all countries invested and committed. Furthermore, any proposals need to be detailed and binding for them to be credible and thus allow stress to return to levels where the market starts to believe in the possibility of a good outcome. As a result, confidence could return and the two forces of market dynamics, greed and fear, could start to coexist again.

[11] We actually think that some type of enforceable contract is needed, rather than just an agreement that turns out to be circumvented once inconvenient

Exhibit 11: Schematic future of the euro crisis

The timeline on the x-axis is for illustrative purposes only. The y-axis measures stress



Source: Credit Suisse

Appendix

Individual player incentives

Germany

Germany benefits from the euro in many ways. Largely due to the size of its net exports but also through the political power it enjoys in the euro as the largest economy; an importance it would struggle to express as a single country due to its history. Germany therefore has a great incentive to keep a large and stable euro region. However, costs of continued bailout programs and the role of the ECB as a lender of last resort worry the population as their deepest fear of inflation is becoming less distant. To some extent, there is also a generational divide. The older generation still has memories of hyperinflation and WWII, while the younger benefits from a lack of that recollection and has grown up in a world without experiencing wars but plenty of international opportunities and relationships. This alone provides for a slow evolution of incentives, but also the rapidly changing economic and financial environment.

France

France’s incentives are to preserve the euro in a stable and ideally not reduced membership form. One of its key objectives is to do so without deteriorating its own creditworthiness and particularly not to lose its AAA rating. It also does not want to suffer a reduction in power relative to other sovereigns, particularly Germany. This is obviously hugely impacted by European history but also plays an even more important role in an election year like 2012. French political leaders still have in mind that the rejection of the European Constitution in 2005 was partly due to the fear of losing their sovereignty or having fiscal policies imposed. For example, the fact that the French opposition is against a debt brake in the Constitution highlights one of the important misaligned interests with Germany and makes it therefore less clear if France is a “core” player in the game’s theoretic sense.

The ECB

The ECB has a problem. On the one hand, its mandate is to secure price stability. This is inherited from the Bundesbank whose sole purpose it was to prevent inflation. Furthermore, it is acting as a sort of referee that is supposed to prevent moral hazard. On the other hand, the ECB must be very much aware of the existential threat of a euro breakup. We therefore believe that the ECB would act boldly if and only if an ultimate stress scenario did arise. So far, potentially being accused of treaty breach is still a deterrent.

Italy

Italy has had a very high public debt-to-GDP ratio for many years. Other metrics like household and corporate debt, deficit and relative size of banking sector to economy are not as worrying as for other countries as, for example, Spain. The reason why Italy however is “under attack” by the market is because of its crucial role within Europe as the euro’s third largest economy or as we would phrase it: “because of its position in the capital structure within the euro sovereign CDO.” To put it simply, Italy is the one, if not the key ingredient, for the euro’s survival. This continues after Mr. Berlusconi’s replacement as PM by Mr Monti. One key component is also Italy’s primary surplus. Purely on that basis, a potential threat to not pay its debt – if ever made – would have some credibility.

Greece

The impact of Greece seems to be less important lately. It still has the ability to cause volatility in the markets, but the losses have gone up far into the capital structure of the euro CDO by now. We expect the renewed PSI discussions to generate a couple more negative news items, but would not be surprised if a failure to achieve an agreement will finally be the trigger for a CDS event.

Conditional probabilities

Correlation of the latent variables has a higher impact (i.e., if negative, reduces the conditional probabilities) the lower the unconditional probability of a signal is.

Exhibit 12: Conditional probability as function of correlation

Rows two to five show conditional probabilities as a function of correlation in the first row. The middle column of zero correlation, in this case, also means independence, hence shows the unconditional probabilities.

-0.8	-0.6	-0.4	-0.2	0	0.2	0.4	0.6	0.8
75%	76%	77%	78%	80%	82%	85%	87%	91%
39%	45%	50%	55%	60%	65%	70%	76%	83%
1%	5%	10%	15%	20%	26%	31%	38%	45%
0%	2%	7%	13%	20%	28%	38%	50%	65%

Source: Credit Suisse

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Disclosure Appendix

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