Fuzzy Similarity and Counterfactuals in the Assessment of Default Risk: the Eurozone Crisis and the *Argentinean* Solution

Abstract
We present an approach, based on the notion of fuzzy similarity, to the comparison of economies under default risk. We run a counterfactual analysis of the perspectives of the most troubled countries in the Eurozone compared with Argentina in 2001. This allows us to assess the possibility that these economies will end up following the path of Argentina.
Keywords
Default risk; Counterfactual Analysis; Fuzzy Similarity; Euro-crisis.

1. Introduction

The events that followed the 2008 financial crisis have shown that countries believed to be shielded against financial turmoil were much frailer than thought. Since then numerous voices pointed out the resemblance of the situation in the most challenged countries of the Eurozone with Argentina in 2001[4][5][10][15a]. As it is well known, the convertibility of the Argentinean peso allowed the banks to carry dollar-nominated accounts, making their balance sheets susceptible to financial fragility at rapid exchange rate changes. While the latter were forbidden by law, the current account deficits and the increasing difficulties to pay back external obligations ended up forcing a default of the debt and a sharp and disordered devaluation of the currency. These events seemed, at the beginning, a source of endless mishaps but ended up (together with a rapid improvement of the international prices of Argentinean exports) creating the conditions for a fast rebound of the Argentinean economy [5] [9] [15a].

It is no wonder then than a chorus of experts in various fields started recommending Greece (and eventually other EU members) to follow the Argentinean path [4] [5] [10] [14] [15a] [17] [18]. These arguments, based on rough analogies, deserve a closer analysis, which we intend to carry out in this paper. While this macroeconomic scenario has been analyzed once and again in the macroeconomic literature (as well as by pundits and politicians), since the basis of comparison is a *single* case a strong justification in needed for making this assessment. Helmer y Rescher's ([13]) provide, fortunately, a sound foundation for such procedure. A counterfactual analysis based on the similarity of the two cases is the key. We focus here on such an exercise. To wit: are really the troubled euro-economies and 2001 Argentina *so* similar? And, if so, to what extent should be expect them to default on their debt and abandon the euro, as seen in the perspective of the 2001 devaluation of the peso? The answers to these questions require the formulation of an appropriate notion of similarity among economies and the exploration of means to infer future events out from analogies.

The approach to be followed in this paper consists in applying Zadeh's ([25]) notion of fuzzy similarity to the comparison of the economic status of different nations. This formalization is intended to capture similarities among crisp objects. Nevertheless it is based on degrees of membership to sets of objects, namely those that satisfy some rather imprecisely defined (i.e.

fuzzy) properties. While other approaches to similarity have been explored in the literature (e.g. [1] [2][3] [8] [21] [24]) ours provides the right combination of soundness and simplicity required by the particular problem at hand. We find that 2001 Argentina and the troubled Eurozone countries belong to a common (fuzzy) equivalence class. From this we will draw the degree of possibility to be assigned to a devaluation and change of currency in the light of the events in Argentina a decade and a half ago.

The plan of the paper is as follows. In section 2 we will provide a conventional account of the current economic situation in some European countries and 2001 Argentina. In section 3 we will discuss the epistemological justification for counterfactual analyses and the conditions under which they can be performed. In section 4 we introduce a version of fuzzy similarity and its application to the evaluation of future consequences in similar situations. In section 5 we apply it to the comparison of the aforementioned economies and draw conclusions for the Eurozone. Finally, section 6 concludes.

2. *Crisatvia* and Argentina

The pervasiveness of systemic risk and fragility in some Eurozone economies forces a comparison with the crises in emergent countries at the end of the 1990s and particularly with the end of the convertibility regime in Argentina. In order to present a streamlined argument, let us assume some European country currently affected by the consequences of the 2008 crisis. The most obvious candidate in 2015 could be Greece, but the situation in the other countries in the group known as GIIPS up to 2014 also qualifies, given the features on which we will focus, not to mention the contagion risks of a deepening Greek crisis [23]. To avoid entering into national specifics let us talk of a generic country named *Crisatvia*. To make the comparison with Argentina more focused, we will concentrate on the solidity of the banking system and on the sustainability of public debt.

In 2001, Argentina's banking sector was heavily "dollarized", but its lender of last resort, the nation's central bank, was unable to ensure enough liquidity to face a run. Worse yet, neither the central bank nor the government itself could borrow in international markets to get additional foreign money [9] [15a].

Nowadays the Eurozone banks are entirely "eurized" but, unlike the Argentinean case, their potential lender of last resort, the European Central Bank (ECB), is able to provide unlimited liquidity to back them. Still, it is unclear whether the ECB will always be willing to fulfill this function.

It must be noted that there is a certain analogy in the fact that in one case (Argentina) the debt in nominated in foreign currency while in the other is nominated in a currency which is not

under the control of the country's monetary authority. But unlike in Europe, in Argentina as in other emergent markets, it was impossible to borrow in domestic money.[†]

So, back to our setting, if the ECB does not play the role of lender of last resort, Crisatvia will have to abandon the Euro while its debt will remain nominated in that currency. This is very much like Argentina and its US$ nominated debt after the abrupt end of the convertibility of the national currency (AR$) with the American dollar. The lack of a **Lender of Last Resort** (*LoLR)* is crucial in two aspects. First, once a bank run starts, a *LoLR* would provide liquidity to the domestic banking system. In the case of Argentina this is relevant because of the dollarization of the balance sheet, while in Cristavia because of its impossibility of printing massive amounts of Euros. Second, a *LoLR* is needed when markets no longer roll over a public debt nominated in a currency issued or printed abroad. But notice that the different maturity processes of assets in the two cases leads to different outcomes. In the Argentinean case, the massive outflow of deposits from the banking system triggered the demotion of the convertibility regime, even if the authorities tried to postpone it by establishing what was called "corralito".[‡]

In fact, many analogies can be established between 2001 Argentina and Crisatvia, summarized in the following items [4][5][10][17][18]:

- *Argentina in 2001*

  - *Default risk*: the country could not get all the US$ needed to meet its obligations.
  - *Need of external financing*: a large proportion of its financing requirements must be covered with funds from capital markets, even after adjustments were made in the external sector.
  - *Infeasibility of unbalance of payments*: the economy was in recession and austerity measures were taken, but still foreign borrowing was the main source of resources.
  - *Sustainability in time*: since the amount of the debt depended on the interest rate determined by an increasing risk premium, it kept growing in time.

The consequence of this was:

- *Default*: foreign lenders stopped providing loans. This, on top of an acute recession, induced a lack of liquidity in US$. Large outflows from the banking system forced, in December 2001, first the enactment of severe restrictions on withdrawals and further a default on the national debt.

[†] This is known in the literature as the *original sin* (see [7] and the references therein).
[‡] On June 28, 2015 Greece closed its banks for two weeks to stop massive withdrawals.

- *Devaluation*: the value of national assets fell, due to the depletion of reserves, forcing an abrupt downfall of the exchange rate.

- *Crisatvia now*

  - *Default risk*: it is possible that the country could not get enough Euros to meet its obligations.
  - *Need of external financing*: to repay its large public debt, the country has to increase its borrowing, even after strong austerity measures have been applied.
  - *Infeasibility of deeper fiscal adjustments*: the political situation restricts severely the possibility of further cuts in fiscal expenditures.
  - *Sustainability in time*: since the amount of debt depends on the interest rate determined by an increasing risk premium, it keeps growing in time.

  The country faces the following risks:
  - *Default*: because of the lack of enough euros.
  - *Loss of the Euro as national currency*: to facilitate a devaluation of the currency.

In both cases the assessment of the sustainability of the national debt required (and requires) conjecturing the reaction of the entire market, very much like in Keynes' Beauty Contest. These economies may support multiple equilibria, with either low or high risk premiums. Therefore, the country may default on its debt as a result of a self-fulfilling prophecy: if most of the lenders think that a default will ensue, the risk premium will be high, making the debt unsustainable and leading to a default on the debt [19]. Alternatively, a strong support of the lenders may lead to a reduction of the risk premium which in turn would make the debt more sustainable, averting catastrophic outcomes.

As discussed above, the danger of default can be avoided if the country has a *LoLR*. Argentina lacked one (able to provide all the US$ needed), while the European Central bank could act as such for Crisatvia.[§] But this depends on many factors, some of them of political nature, but if the ECB leaves Crisatvia on its own, it will increase the risk for other Eurozone countries as well. If the ECB abandons Crisatvia, the country might be forced to default and return to its former currency, devaluated with respect to the Euro, but keeping its defaulted debt nominated in the European money. If, instead, the ECB acts in behalf of the country, the default might be averted. But in this case the Crisatvian economy will be in recession, albeit honoring

[§] Even if the statutes of the ECB do not allow acting as such, it could change them to facilitate the provision of liquidity in case of need.

its debt without increasing it. The latter is by itself a politically challenging scenario, but is not of concern for the analysis in this paper.

In either case, to forecast the future perspectives of the Crisatvian economy involves a counterfactual claim. We would like to make this claim using just empirical information, instead of running a macroeconomic model. But this means to look at "similar" cases. This is where the comparison with Argentina becomes relevant.

As a control variable for this comparison, we add another case, namely that of the USA. Notice the USA does not differ in *every* aspect from the other two cases [15b]. For one thing, it shares with them the burden of high debt. But, the dangers of facing a "fiscal cliff" make it easier to adjust the amount of public spending and tax revenues and moreover, being able to print its own money, the USA can act as its own *LoLR* and has the means to make its debt sustainable. The potential cost is an inflationary surge, but this consideration would lead us to a different terrain.

In either case we will define a measure of *Default risk* of a country *B* in terms of a comparison with the case of country *A*. Our goal is to apply this measure to the assessment of the perspectives of Cristavia (in de role of country *B*) in terms of those of Argentina (alternatively the USA) as country *A*.

3. Counterfactual reasoning

The methodology of analysis to be pursued here follows the prescription given by Helmer and Rescher in their analysis of the epistemology of inexact sciences, in particular, in the discussion on the nature of the so-called "historical laws" [13]. Their point of view is that research in history can be deemed as scientific only if it intends to determine the validity of claims about historical events. These claims must be propositions concerning the actions of one or more human groups subject to certain constraints. If the claims are shown to be true, they can be seen as representing historical laws.

Nevertheless, the scope of the term *law* must somehow be restricted in order to keep it being different from the meaning in physical sciences. The confirmation of claims is clearly less applicable than in those sciences, and the presence of counterexamples does not always imply the non-validity of historical claims. In consequence, Helmer and Rescher redefine the class of propositions that can be candidates to represent historical laws. Firstly, they have to be vague enough to not be falsified trivially by counterexamples. Secondly, they have to be legaliform, that is, they must be able to be used as explanations (and therefore not be mere descriptions of facts) and finally, they must have counterfactual power. This means that they have to be able to explain events to which they do not make direct reference. Their shape must thus be:

If system $\mathcal{S}$ reaches value s, event x* will happen*

To confirm a statement of this form the counterfactual method is required. That is, to check its validity in a context "close" to the real one, in which *s** is accompanied by *x**. That is:

If given a system $\mathcal{S}$' such that $\mathcal{S}$ and $\mathcal{S}$' are close, and in $\mathcal{S}$' at state s it is the case that x* happens, then in $\mathcal{S}$ at state s* it should also happen x**

The degree of arbitrariness reflected in the notion of closeness is higher than in more exact disciplines, requiring expertise to fix the degree of precision required in establishing the validity of a statement. The statement is true if, in an alternative, close to the one under analysis, the validity of the antecedent goes together with the validity of the consequent.

This notion is due to Robert Stalnaker ([22]) and David Lewis ([16]). But a crucial component is the notion of closeness among cases. It is quite difficult to say that *everything is identically true*. In practice, the method consists of finding a context that minimizes the differences with the one under analysis.

In our approach we will consider a class of *situations* **S**, where each $s \in \mathbf{S}$ is $s = (\mathcal{S}, s^*)$, a pair consisting of a system and a state. On the other hand, the consequences like *x** will belong to a class **K**. Then, for $s = (\mathcal{S}, s^*)$, $t = (\mathcal{S}', s^*)$ and $x^* \in \mathbf{K}$, the goal of our counterfactual assessment can be summarized as (where $\wedge$ indicates conjunction and $\Longrightarrow$ logical implication):

$$\text{Close}(s, t) \wedge \text{Consequence}(s, x^*) \Longrightarrow \text{Consequence}(t, x^*) \qquad (\mathbf{1})$$

Notice that the state component of a situation is not system-specific. Otherwise it would be useless for this exercise. To avoid this possibility, "state" will mean for us the way in which a system satisfies a class of properties that can be predicated over the different systems under analysis. It is on the basis of these degrees of satisfaction that our notion of closeness will be defined.

4. Fuzzy similarity

To carry out the counterfactual assessment described by (**1**) we need to formalize the notion of closeness to be used. Since it involves the quantitative idea of similarity, we appeal to its original formalization due to Zadeh ([25]).

Let us consider an abstract class of elements **S** understood as situations. This similarity between situations can be defined in terms of a binary relation $\Phi \subseteq \mathbf{S} \times \mathbf{S}$. But since this is a crisp set, in which membership is either true or false, making it too precise for our needs, we

will appeal to fuzzy similarity, in which membership is up to a degree. We consider the fuzzy similarity in **S** x **S** to be given by the following membership function:

$$\mu_\Phi: \mathbf{S} \times \mathbf{S} \rightarrow [0,1]$$

To be a similarity relation, μ_Φ has to fulfill the following properties [6]:

- ***Reflexivity***: for every $s \in \mathbf{S}$, $\mu_\Phi(s,s) = 1$.
- ***Symmetry***: for every pair of elements $s,t \in \mathbf{S}$, $\mu_\Phi(s,t) = \mu_\Phi(t,s)$.
- ***Max-min Transitivity***: for every triple $s,t,u \in \mathbf{S}$, $\mu_\Phi(s,u) \geq \min(\mu_\Phi(s,t), \mu_\Phi(t,u))$, where min(A,B) is A if B≥A, and B otherwise.

Of interest for our purposes is the class of corresponding α-cuts of μ_Φ. It is a trivial consequence of the properties of a fuzzy similarity relation that:

- μ_Φ is a similarity if and only if $\mu_\Phi^{\alpha} = \{(s,t): \mu_\Phi(s,t) \geq \alpha\}$ is an equivalence relation in **S** for every $\alpha \in (0, 1]$.

Two situations *s* and *t* will be deemed *equivalent* if and only if $\mu_\Phi(s,t) = 1$. Or equivalently, if $(s,t) \in \mu_\Phi^{1}$.

A relevant question is how to derive $\mu_\Phi(s,t)$ from the individual assessments of *s* and *t*. Our proposal consists in considering a finite family of criteria $\mathbf{C} = \{c_1, \ldots c_n\}$, in which each criterion c_i is such that c_i: $\mathbf{S} \rightarrow [0,1]$, i.e. it is a fuzzy membership function indicating the degree in which a situation satisfies the criterion. Then, according to the i-th criterion, the similarity between two situations s and t is given by $\mu_i(s,t) = \min(c_i(s), c_i(t))$, i.e. the degree of similarity between *s* and *t* should be as strong as the lowest degree in which the criterion is satisfied.

In turn, the similarity between two situations *s* and *t*, evaluated according the whole family of criteria **C** cannot exceed the lowest degree of similarity according to the criteria. That is:**

** Notice that other ways of characterizing $\mu_C(s,t)$ can be defined. For instance by using weights on the criteria, lending more importance to the degree in which the more relevant criteria are satisfied. Or taking the taxi-cab distance between *s* and *t* ($\mu_{\mathbf{C}}(s,t) = [1 + \Sigma_{i=1..n}\ \mu_i(s,t)]^{-1}$) or the Euclidean distance between them ($\mu_{\mathbf{C}}(s,t) = [1 + (\Sigma_{i=1..n}\ (\mu_i(s,t))^2)^{-1/2}]^{-1}$), etc.

$$\mu_{\mathbf{C}}(s,t) = \min(\mu_1(s,t),\ldots, \mu_n(s,t)) \qquad \textbf{(2)}$$

The assumption here is that for every pair $s,t \in \mathbf{S}$, the degree in which the relation Φ is satisfied equals the degree of satisfaction of the criteria in **C**. More precisely, for every pair $s,t \in \mathbf{S}$,

$$\mu_{\Phi}(s,t) \geq \alpha \text{ if and only if } \mu_1(s,t) \geq \alpha \text{ or } \ldots \text{ or } \mu_n(s,t) \geq \alpha \qquad \textbf{(*)}$$

Then, it follows that:

Proposition 1: *For every pair* $s,t \in \mathbf{S}$, $\mu_{\mathbf{C}}(s,t) = \mu_{\Phi}(s,t)$.

Proof: *Suppose that for a given pair* $s,t \in \mathbf{S}$ *and* $\alpha \in (0,1)$, $\mu_{\Phi}(s,t) < \alpha$ *while* $\mu_{\mathbf{C}}(s,t) \geq \alpha$ (*the same is true if* $\mu_{\Phi}(s,t) \geq \alpha$ *while* $\mu_{\mathbf{C}}(s,t) < \alpha$). *By* **(*)**,$\mu_{\Phi}(s,t) < \alpha$ *is equivalent to* $\mu_i(s,t) < \alpha$ *for every* i=1,…,n, *i.e.* $\min(\mu_1(s,t),\ldots, \mu_n(s,t)) < \alpha$. *But this means that* $\mu_{\mathbf{C}}(s,t) < \alpha$. *Contradiction*.

Consider now the class of consequences that may ensue in situations of **S**, denoted **K**. The degree in which a situation $s \in \mathbf{S}$ may yield a consequence $x^* \in \mathbf{K}$ will be captured by a fuzzy membership function ρ: **S** x **K**→ [0,1]. In our counterfactual exercise **(1)** we assumed that *s* had already consequence *x**, while *t* had yet to yield a consequence. So the degree of verisimilitude of the claim that *t* will have consequence *x** can be represented by $\rho(t, x^*)$, while $\rho(s,x^*)=1$ since we know that *s* had *x** as a consequence. We have then:

Proposition 2: $\rho(t,x^*) \geq \mu_{\Phi}(s,t)$.

Proof: *Trivial. In an implication the consequent has at least the degree of validity of the antecedent, so* $\rho(t,x^*) \geq \min(\mu_{\Phi}(s,t), \rho(s,x^*))$. *But since* $\rho(s,x^*)=1$, $\min(\mu_{\Phi}(s,t), \rho(s,x^*)) = \mu_{\Phi}(s,t)$.

On the other hand, if we fix a degree in which we believe **(1)**, say $\beta<1$, we have:

Proposition 3: $\rho(t,x^*) = \mu_{\Phi}(s,t)$ *if* $\mu_{\Phi}(s,t) \geq \beta$ *and* $\beta > \rho(t,x^*) \geq \mu_{\Phi}(s,t)$, *otherwise*.

Proof: *this follows from Proposition* 1 *and the characterization of modus ponens in* [6] *(pp. 167).*

We can define an *inference gap* measure of the discrepancy between a conclusion and the inference rule from which it is obtained, as $\mathbf{I}_{A,B} = \min(0, \mu_B - \mu_{A\rightarrow B})$, for any inference rule A→B (where $\mu(\cdot)$ is the fuzzy membership function). In particular, if the degree in which **(1)** is believed is again $\beta<1$ we have $\mathbf{I}_{((s,x^*),(t,x^*))} = \min(0, \rho(t,x^*) - \beta)$. Then:

Proposition 4: $\mathbf{I}_{((s,x^*),(t,x^*))} = \mu_{\Phi}(s,t)$.

Proof: *Immediate from Proposition 3.*

5. Argentina and Crisatvia revisited

We say the *Default Risk* of a country B in comparison with the case of country A is represented as $\mathbf{I}_{((\text{CountryA, Default}),(\text{ CountryB, Default}))}$. Then:

Lemma 1: $\mathbf{I}_{((\text{CountryA, Default}),(\text{ CountryB, Default}))} \leq \rho(\text{Country}_B, \text{Default})$.

Proof: *It follows from the definition of* $\mathbf{I}_{((\text{CountryA, Default}),(\text{ CountryB, Default}))}$ *and Propositions 3 and 4.*

To apply this result we have to construct the similarity relation. As an intermediate step we will consider some *linguistic variables* [11] [12]. In this case, variables that have values in natural language: **low** (*l*), **medium-low** (*m-l*), **medium** (*m*), **medium-high** (*m-h*) and **high** (*h*), indicating the degree of fulfillment of criteria. Then, we will consider a degree in which Crisatvia and the USA nowadays and Argentina 2001 satisfy the following criteria: *Highly Indebted*, *Unable to Make Large Adjustments*, *Un-sustainability of the Debt* and *Has no Lender of Last Resort*.

The degree of fulfillment of these criteria is hard to assess, since their evaluation and classification involves a heavy component of prognostication and inexactness. According to Helmer and Rescher ([13]) this a case in which an expert poll method is more appropriate. From the many methods in the literature we have chosen Delphi, a method in which a group of (mutually anonymous) experts are questioned and then the collective answers (without the identity of the responders) are repeatedly feed backed to them, until either an agreement or two distinct assessments is obtained [20]. The following table summarizes the agreement result in the application of the Delphi method to our case:[††]

	Argentina	**Crisatvia**	**USA**
Highly Indebted	h	h	h
Unable to Make Large Adjustments	h	h	m
Un-sustainability of the Debt	h	m-h	l
Has no Lender of Last Resort	h	m	l

Degrees of satisfaction of the main criteria

[††] We ran a Delphi poll of five Argentinean macroeconomists that have been either publishing or blogging on the possibilities of "Grexit" during June/July of 2015.

If we translate the linguistic variables into numerical values, say low (0.1), medium-low (0.3), medium (0.5), medium-high (0.7) and high (0.9), we can obtain, using **(1)**:

$$\mu_{\Phi}(\text{Argentina,Crisatvia}) = \min(0.9, 0.9, 0.7, 0.5) = 0.5$$

while

$$\mu_{\Phi}(\text{USA,Crisatvia}) = \min(0.9, 0.5, 0.1, 0.1) = 0.1$$

On the other hand, we have that while ρ(Argentina, Default) = 1 (corresponding to the linguistic variable *true*), the value of ρ(Crisatvia, Default) can be determined if we lend a medium-high degree to the belief in the claim that Argentina 2001 and Crisatvia are in a similar state:

$$\rho(\text{Crisatvia, Default}) \in [0.5, 0.7)$$

This result is obtained from Lemma 1 when $\beta = 0.7$. This leads to a constrained degree of belief (between medium and medium-high) in the possibility of a default in Crisatvia. On the other hand, since the belief in the USA and Crisatvia being in a similar situation should be given a low degree, the comparison between them yields:

$$\rho(\text{Crisatvia, Default}) = 0.1$$

This indicates clearly that the USA cannot be a basis of comparison with Crisatvia. On the other hand this result, combined with the comparison with Argentina, shows that the prospects of default should not be deemed excessively high for Crisatvia just on the basis of some similarities with other cases.

6. Conclusions

In summary, we obtained two interesting qualitative assessments. The first one is that far from being completely analogous, currently troubled Eurozone countries have only a half-way resemblance with Argentina in 2001. The main reason is that while the latter lacked a lender of last resort, the European Central Bank (plus other relevant international organizations) could still act as such for the Eurozone countries.

This fact has in turn another consequence: it reduces the degree in which a default can be expected in the Eurozone. The coverage provided by the *LoLR* makes a default less than certain. In summary, this exercise indicates that the perspectives in the Eurozone are less bleak than they were ten years ago in Argentina.

On the other hand, this problem required a new framework of analysis, combining counterfactual reasoning and the use of fuzzy similarity. Future work involves the development

of a full forecasting methodology based on these ideas, but on the basis of actual data (not just expert assessments) and of other notions of similarity.

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