Modelling Crises: the Example of the Spanish Economy

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Abstract

We examine in this paper the stability or otherwise of the financial system in Spain, and in particular the stability of the savings banks.

We respond to the comments of Jean-Claude Trichet when he was Governor of the European Central Bank in November 2010: 'As a policy-maker during the crisis I felt abandoned by conventional tools.. . . .we need to develop complementary tools to improve the robustness of our overall framework. In this context, I would very much welcome inspiration from other disciplines: physics, engineering, psychology, biology'.

Complex systems, such as economies, are notoriously difficult to predict. Spain´s economic problems arise not from a single destructive factor, but rather a nexus of inter-related and interdependent factors. While none of these alone may be enough to push Spain over the edge, their interaction and mutual impacts could provoke a "tipping point" effect. Human analysts find such complex interactions difficult to track. Dynamic modelling offers a way of getting purchase on the issues.

In conjunction with a financial sector institution, we identified a small number of key determinants of stability: unemployment; bad debt of savings banks; regional/local government bad debt; spread on government bonds; international sentiment; property prices; economic growth

We model these as a dynamic system with *feedbacks* between the various factors.

The key question is whether these feedbacks amplify or contain shocks to the system. In general, the conclusion is that the financial system in Spain is distinctly vulnerable to adverse shocks. The shocks tend to be amplified by the feedbacks rather than dampened.

We also examine the stability of the system with respect to a wide range of initial conditions. We find that in the current circumstances, the values of almost all the variables in the system lie in the range which is typically associated with instability rather than stability.

1 Introduction

In economics as well as politics, the track record on prediction is extremely poor by scientific standards, especially in terms of forecasting major turning points such as recessions. By way of example, in August 2008, the consensus forecasts for GDP growth in 2009 were still positive in the US, UK and the main European economies. This, it need hardly be said, was less than a month before the financial crisis deepened spectacularly in the week of 15 September 2008[1]. Needless to say, the growth outcomes for 2009 were uniformly negative as the West experienced the worst recession since the 1930s.

[1] See, for example, Figure 4 in the *Bank of England Quarterly Bulletin*, October 2008

Ormerod and Mounfield (2000), for example, show that there is a deep reason for the poor prediction record on macroeconomics. In most Western countries, data on annual GDP growth in many economies is hardly distinguishable from a random series. The implication is that it is simply not possible to produce systematically accurate forecasts of GDP growth, no matter what economic theory or statistical technique is used.

A fundamental reason why expert judgement so frequently fails to anticipate political developments, and in particular major changes (Tetlock, 2005), is that the social and economic worlds are complex systems in which dynamic feedback between the component parts means that the future is inherently very difficult to predict.

But it is not merely in the matter of prediction that conventional approaches have performed badly. They failed to provide reasonable *explanations* of the financial crisis. In the social sciences in general, there is a fundamental distinction to be made between the two concepts of prediction and explanation (see, for example, the papers in Squazzoni, ed., 2006 and Squazzoni 2012).

In November 2010, European Central Bank (ECB) then Governor Jean-Claude Trichet opened the ECBs flagship annual Central Banking Conference with a challenge to the scientific community to develop radically new approaches to understanding the economy:

"When the crisis came, the serious limitations of existing economic and financial models immediately became apparent. Macro models failed to predict the crisis and seemed incapable of explaining what was happening to the economy in a convincing manner. As a policy-maker during the crisis I felt abandoned by conventional tools.. . . .we need to develop complementary tools to improve the robustness of our overall framework. In this context, I would very much welcome inspiration from other disciplines: physics, engineering, psychology, biology. Bringing experts from these fields together with economists and central bankers is potentially very creative and valuable. Scientists have developed sophisticated tools for analysing complex dynamic systems in a rigorous way. These models have proved helpful in understanding many important but complex phenomena"

We responded to this challenge by building a dynamic model which focuses specifically on the stability or otherwise of the financial system in Spain, and in particular the stability of the savings banks. Unlike other economic models which are ultimately based on the idea of equilibrium, the specific purpose of the model is to understand and predict crises. We developed the model in conjunction with a London-based financial institution with particular expertise on Spain.

As the Spanish Government has repeatedly argued, the Spanish economy is distinctly different to those of the other periphery countries which have already had to seek EU/IMF support. While Spain does suffer a series of cyclical and structural problems, none alone threatens to overwhelm the economy as a whole (even unemployment at over 20 per cent has proved sustainable so far). Corruption and fiscal irresponsibility exist, especially at municipal and regional level, but not endemically at all levels as in Greece. The fiscal deficit has increased, but not to Portuguese levels. There are genuine concerns about the stability of the savings banks ("cajas de ahorro" – two have effectively collapsed), but Spain has yet to suffer a collapse of its banking system comparable to Ireland.

Spain´s problem, and the risk to its economic viability, lies in the nexus of different factors which affect and impact on each other. It is the combination and interaction of otherwise manageable economic problems which risk producing a "tipping point" or "phase transition" which pushes the Spanish economy into a deeper crisis. This makes the Spanish economy particularly difficult for analysts used to focusing on single, or at most a small number of factors. Some studies suggest that human decision-makers can normally handle only three factors over a maximum of six steps. The Spanish economy requires a more complicated analysis.

Kosko (1986) and Dickerson and Kosko (1994) develop the concept of a fuzzy cognitive map, or FCM. This is a concept which draws a causal picture between the key factors in any given situation. In particular, it allows for dynamic feedback between these factors.

Whilst recognising the fundamental limitations of any methodology which claims to be able to predict the future in human systems, in this study we utilise the concept of an FCM to think about the stability of the Spanish economy.

Judgement plays a crucial role in this approach but the key point of the approach is that it enables the full implications of judgement to be explored. In particular, it might be able to help identify the conditions under which a particular set of expert judgements might lead to an extreme event, one which would be otherwise unanticipated.

The model focuses specifically on the stability of the Spanish financial system. This is key both to the decisions of overseas investors and to the ability of the Spanish Government to meet its debt commitments. Directly this depends on levels of bad debt and international sentiment. But indirectly, and crucially, it will depend on factors such as unemployment, sub-national government debt and property prices. The modelling technique we have used seeks to facilitate understanding of the inter-relationships between these factors and their consequences for the Spanish financial system.

2 Model Specification

The outcome which we are seeking to understand through our modelling is the stability of the Spanish financial system.

We set up a formal, programmed model, through which we can explore the factors which impact upon financial stability. The approach is reliant upon judgment in a number of key ways. First, we must identify the causal factors which we believe are important. We then need to determine the direction of causation between all factors. Having identified these causal factors we must then decide the relative strength of the linkages involved.

Essentially, the model captures the tacit knowledge (Polanyi, 1958) of the relevant experts in the financial sector institution involved in the project. However, it is important to point out that the process of developing the model did not simply consist of interviews and discussions with them and using this material to construct the model. This was a necessary first step. But then, the results of the model were presented to the experts, showing them the implications of the feedbacks between the various factors which they believed to be important. The model was modified in the light of this, the implications of the system as a whole being in some respects not what the domain experts has expected. Several iterations of this process were required before the domain experts felt comfortable with the properties of the system developed on the basis of their judgements.

Of course, it is always open to a different set of domain experts to arrive at either a different set of factors, or the same factors but with different feedbacks and/or strengths of the individual feedbacks.

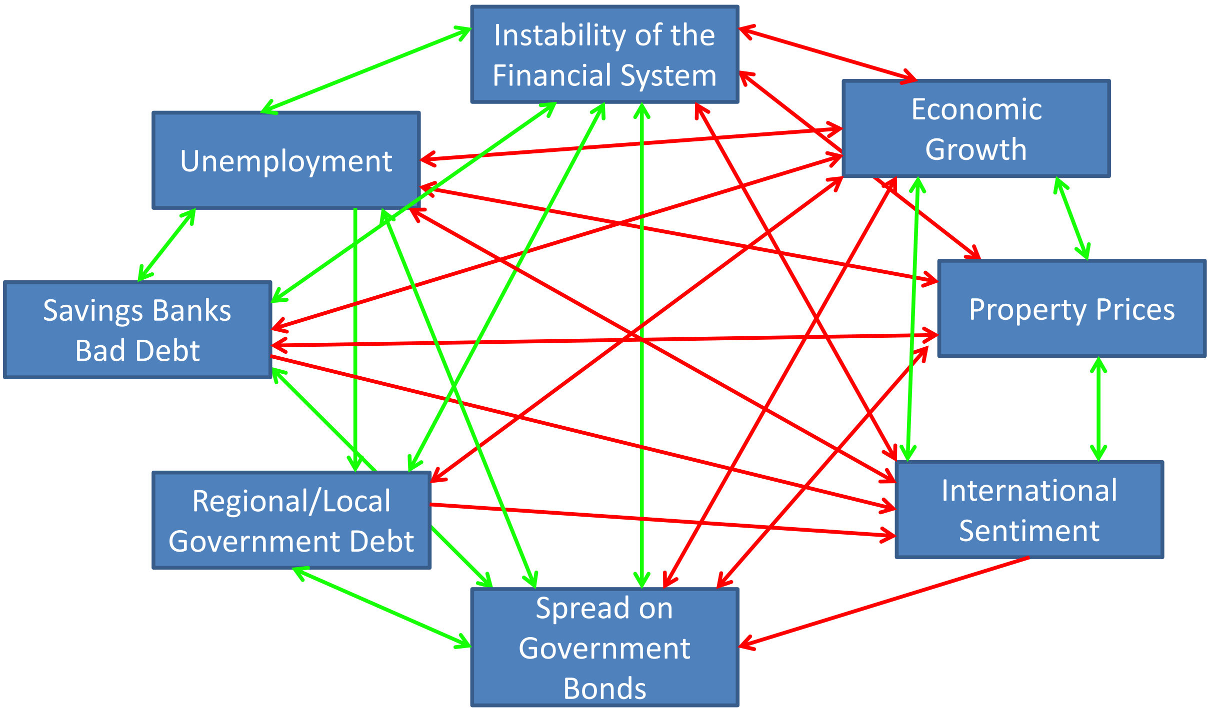
The approach could therefore be criticised as merely reflecting judgement. However, even when allegedly more scientific approaches are used, economics has failed to reach a consensus on many fundamental features of the macro economy. For example, at the height of the financial crisis and the debate in the US about the Troubled Asset Relief Programme and the measures to save the banks, one set of economists argued in favour of even more government intervention, whilst another group believed just as vociferously that governments should do less and that banks should be allowed to fail. Both groups included Nobel Laureates.

As a further example, a fundamental concept in macroeconomic theory is the size of the fiscal multiplier, one which is taught to all students of economics. The idea was introduced by Keynes in the 1930s. But even now, almost 80 years later, the economics profession is very far from arriving at a consensus on the value of the multiplier in practice.

This is despite decades of intensive statistically-based analysis of the data. So, for example, Ramey (2011) argues that the multiplier in the US, which is of course a much more closed economy in trade terms than any individual European economy, is between 0.8 and 1.5. However, Barro and Redlick (2011) argue that multipliers for non-defence purchases cannot even be reliably estimated at all because of a lack of suitable instruments. They conclude that: 'The estimated multiplier for defense spending is 0.6-0.7 at the median unemployment rate. There is some evidence that this multiplier rises with the extent of economic slack and reaches 1.0 when the unemployment rate is around 12%. Since the defense-spending multiplier is typically less than one, greater spending tends to crowd out other components of GDP.'

The model is shown in Figure 1. Blue boxes denote causal factors, red lines denote negative relationships and green lines denote positive relationships

Figure 1 *Factors which impact upon stability of the Spanish financial system*



Our principal focus with this model is whether the financial system is stable. Given a set of initial values for the variables and a set of values for the parameters which indicate the strength of the links, we want to know whether the feedbacks in the model will lead to the financial stability variable rising or falling in value from its initial level. If it rises, the system is unstable and stable if it falls.

Whilst we have made this model as simple as possible, it already contains a significant amount of judgment and already looks rather complicated. We describe below the relationships in the model:

a. An increase in unemployment:

- Increases financial instability
- Increases bad debt levels in savings banks
- Increases regional/local government debt
- Impacts negatively on economic growth
- Impacts negatively on property prices
- Increases the spread on government bonds
- Impacts negatively on international sentiment

b. An increase in bad debt in savings banks:

- Increases financial instability
- Increases unemployment
- Impacts negatively on economic growth
- Impacts negatively on international sentiment
- Impacts negatively on property prices
- Increases the spread on government bonds
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c. An increase in regional/local government debt:

- Increases financial instability
- Impacts negatively on economic growth
- Impacts negatively on international sentiment
- Increases the spread on government bonds

d. An increase in the spread on government bonds:

- Increases financial instability
- Increases regional/local government debt
- Increases unemployment
- Increases bad debt in savings banks
- Impacts negatively on economic growth
- Impacts negatively on property prices

e. Improved international sentiment:

- Reduces financial instability
- Increases property prices
- Increases economic growth
- Reduces the spread on government bonds
- Reduces unemployment

f. An increase in property prices:

- Reduces financial instability

- Increases economic growth
- Increases international sentiment
- Has a negative impact on unemployment
- Reduces bad debt in savings banks
- Reduces the spread on government bonds

g. Economic growth:

- Reduces financial instability
- Reduces the spread on government bonds
- Increases property prices
- Increases international sentiment
- Reduces bad debt in savings banks
- Reduces unemployment
- Reduces regional/local government debt

h. Increased instability of the financial system:

- Reduces economic growth
- Reduces property prices
- Impacts negatively on international sentiment
- Increases the spread on government bonds
- Increases bad debt in savings banks
- Increases unemployment
- Increases regional/local government debt

The next step in the modelling is to decide on the relative strength of each of these factors. These are detailed in the table below, and have been arrived at through discussion with the client. This means that, for example, an increase in international sentiment will result in an equal and opposite impact upon the spread on government bonds. In addition, we decide the initial values of the variables. What matters here is the relative value in the sense whether the value of any given factor is high or low, so we choose these values in the interval [0,1].

Figure 2 *Relative strength of the linkages in the model*

		Impact from...							
		Unemploy-ment	Spread on Govt bonds	Savings Banks Bad Debt	Regional / Local Govt Debt	Inter-national sentiment	Economic growth	Property prices	Instability of the Financial System
Impact on...	Unemploy-ment	0	0.1	0.2	0	-0.1	-0.8	-0.2	0.2
	Spread on Govt bonds	0.3	0	0.5	0.5	-1	-0.6	-0.2	0.7
	Savings Banks Bad Debt	0.6	0.3	0	0	0	-0.5	-0.8	0.2
	Regional / Local Govt Debt	0.1	0.2	0	0	0	-0.7	0	0.1
	Inter-national sentiment	-0.3	0	-0.6	-0.3	0	0.9	0.3	-0.5
	Economic growth	-0.8	-0.3	-0.3	-0.1	0.4	0	0.2	-0.3
	Property prices	-0.3	-0.2	-0.7	0	0.2	0.4	0	-0.5
	Instability of the Financial System	0.3	0.6	0.7	0.2	-0.7	-0.8	-0.6	0

As is often the case in mathematics, a problem can be expressed in both geometric and algebraic ways. For example, Pythagoras's theorem can either be visualised as a right-angled triangle or as the algebraic expression $a^2 = b^2 + c^2$. Figure 1 is the geometric representation of the map. The factors in the boxes represent the *level* of that variable at a point in time. The connections into it from other boxes describe how the level changes as other variables change, and connections out from it to other boxes show how changes in the variable affect the levels of other variables. In short, we have a system of linear differential equations:

$$dx/dt = Ax \qquad (1)$$

where x is a vector in eight dimensions, A is an 8x8 matrix of the connections and on the right hand side Ax is the product of the matrix A and the vector x.

The stability properties of the system around any equilibrium solution to these equations depend in a straightforward way on the eigenvalues of the matrix A. If all the eigenvalues of A have negative real parts, equilibrium is stable. In other words, disturbances to the system away from a stable equilibrium will be absorbed. On the other hand, if all eigenvalues have positive real parts, it is an unstable equilibrium point, any initial movement away from it, no matter how small, will be amplified. The remaining case is when the real parts of some of the eigenvalues are positive and of the others negative. This makes the point a saddle point and the stable axes are in the direction of the eigenvectors corresponding to the eigenvalues with negative real part, the other eigenvectors determine the unstable axes since their corresponding eigenvalues have positive real part. In other words whether a system will absorb a disturbance or whether it will become unstable depends on the nature of the disturbance.

When the links take the values as given in Figure 2, the stability properties are indeed revealed to be complicated. Three eigenvalues of *A* have positive real parts, of 2.56, 0.25 and 0.11, so shocks in the directions corresponding to this are not stable, they will be amplified. But the other five all have negative real parts, so that shocks here would be absorbed, and the feedbacks would prevent them from being amplified[2].

Once we have decided on the values of the linkages (the model parameters) we can then run the model to see whether it is stable or unstable. In order to run the model, we must allocate initial values to each of the factors and values to each of the links between factors.

We can solve the model numerically many times, in each case drawing both the initial values of the variables and the strength of the linkages from a designated range of values. This enables us to form a general picture of the potential stability of the system.

We can define the values for the parameters in two ways. Firstly, we can simply take the strength of each link to be exactly equal to the numbers in Figure 2. Secondly, we can allow each of the linkages to be picked randomly between 0.1 above and below the central values given in Figure 2.

3 Results

The initial conditions were set as follows:

Figure 3 Initial conditions

Unemployment	0.8
Spread on Government bonds	0.6
Savings Banks Bad Debt	0.7
Regional/Local Govt Debt	0.6
International Sentiment	0.2
Economic Growth	0.1
Property prices	0.1
Instability in Financial System	0.4

[2] When the initial conditions are not at an equilibrium point, these statements remain true provided that the initial conditions in n-dimensional space are within the attractor space of the relevant root

We investigated the sensitivity of this result to variations in both the parameters and the initial conditions. We ran the model 1,000 times in each case. First, we allowed the parameters to vary by drawing from a uniform distribution each time for each parameter, with a range of ± 0.1 around the central values in Figure 2 and the initial values drawn randomly between 0 and 1. We then kept the parameters fixed and drew the initial values in the same way, from a uniform distribution between 0 and 1. Next we considered these two options (fixed and varying parameters) with the initial values drawn with a range of ± 0.1 around the central values in Figure 3. We find that the results are not sensitive to the range of the parameters, being unstable in around 70-75 per cent of the solutions in each case. However once we draw the initial conditions around the central values in Figure 3 the model is unstable all of the time. In other words, the current situation in Spain is likely to lead to financial instability.

We set out below the average values of the initial conditions (with both varying and fixed parameters for the links, and the initial conditions drawn randomly between 0 and 1) in the solutions in which the results are stable and unstable respectively.

Figure 4 ***Average initial values of variables for stable and unstable solutions***

	Fixed links		Varying links	
Initial values of variables	Average if stable	Average if unstable	Average if stable	Average if unstable
Unemployment	0.37	0.57	0.35	0.55
Spread on Government bonds	0.44	0.53	0.36	0.53
Savings Banks Bad Debt	0.38	0.54	0.36	0.55
Regional/Local Govt Debt	0.47	0.53	0.46	0.50
International Sentiment	0.61	0.46	0.62	0.45
Economic Growth	0.68	0.43	0.68	0.42
Property prices	0.63	0.44	0.62	0.46
Instability in Financial System	0.36	0.56	0.43	0.57

Looking at the results it is evident that the stable results are characterised by higher initial values of Economic growth, Property Prices and International Sentiment and lower initial values of Savings Banks Bad Debt, Spread on Government Bonds, Unemployment and Regional / Local Government Debt, as well as lower initial values for the Instability of the Financial System variable.

We can usefully compare these values with the central values of the initial conditions set out in Figure 3. In each case, we see that the initial values lie above the averages associated with unstable solutions, with one key exception. The central value for the initial value of the financial instability system was chosen to be 0.4. This is virtually identical to the average value of initial conditions in which, other things being equal, the system would be stable. However, other things are most decidedly not equal. It is the initial conditions for the other variables which lead to the clear majority of solutions being unstable. If these could be altered, the prospects for Spain would look much brighter.

4 Conclusions

If the judgements on which the model is based are correct, then the Spanish economy appears to be unstable and highly vulnerable to shocks. This appears especially true of the financial sector, which the model was designed to test. Negative feedback loops, which enhance stability, appear to be outweighed by the positive feedback loops which exaggerate the impact of shocks. This could have serious implications both for investors and policy makers. Spain is already subject to what many analysts regard as negative external shocks in the form of high fuel prices and the increase in interest rates by the ECB. The model suggests that if either of these are sustained, it could question the viability of the Spanish financial system.

The model may suggest that the stress tests applied to Spanish financial institutions (and especially the savings banks ("Cajas de Ahorros") by the Bank of Spain are insufficiently rigorous, or possibly too narrow in their conception of stress. They may take insufficient account of the complexity of the system in which the savings banks operate and the multitude of factors that directly or indirectly impact on their viability. At the very least, it can be said that the model raises more concerns about the future of the financial system than the Bank of Spain.

The key positive factors that ameliorate the prospects for the financial system are property prices, economic growth and international sentiment. The key negative factors are bad debt (sub-national government and savings bank), unemployment and the spread on bond yields. Bond yields and international sentient to some extent trade off, suggesting that policy makers should focus on sanitising debt, unemployment and restoring the property market. Government policies have so far not focused on these areas in a consistent way (nor have international investors or organisations focused on these particular areas either). These may provide useful benchmarks for analysts.

The conclusions of this paper are dependent on the initial analytical judgements. The modelling technique makes explicit the implications of those judgements.

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