Free-riders to forerunners

Full author list: Klaus Hasselmann, Roger Cremades, Tatiana Filatova, Richard Hewitt, Carlo Jaeger, Dmitry Kovalevsky, Alexey Voinov and Nick Winder

Model structure

We consider the evolution of the euro economies of the northern (creditor) and southern (debtor) countries during the euro crisis in terms of an idealized stocks-and-flows, two-country (North-South) model based on four key actors (banks, firms, households and governments) in each country. Each actor is characterized by a stock of money (box) and money flows (hour glasses) to neighbouring actors. It is assumed that the net money flows for firms and households both sum to zero; thus money is accumulated only by governments and banks.

The money flows translate into similar flows of consumer goods and services and work provided, assuming a constant (inflation adjusted) price of the total goods and services produced and total wages paid. However, consumer goods and services, in contrast to money, cannot be accumulated, but only consumed. Thus the stocks-and-flows balance for consumer goods and services differs in detail from the money flows.

We consider three scenarios (Figure 2). In scenario 0, it is assumed that
the southern government runs a constant budget deficit. Starting from an arbitrary initial government capital of zero, the southern capital decreases approximately linearly, the debt being balanced by a corresponding credit from the northern government. Interest payments, set at 4%, slightly increase the rate of growth of the debt as the debt accumulates. Assuming an annual budget of 100 MU/year, measured in arbitrarily defined monetary units MU (of the order of $10^9$ euro) and a budget deficit of 10%, the southern government debt grows to 200 MU within about fourteen years. The southern government debt is balanced by a credit from the northern government. The connection between southern government debt and northern government credit follows a clockwise path in the six upper-right boxes of Figure 1: underpayment of taxes by southern households enables the purchase of more goods from firms in the South; the additional goods are imported by southern firms from northern firms; households in the North buy correspondingly less goods; the reduced purchasing power of northern households follows, finally, from the increased taxes paid to the northern government to finance the credit accorded to the southern government.

From the point of view of households and firms, scenario 0 represents a stable stationary state. If government debts and credits are simply ignored or forgotten (for which there exist many contemporary examples), all participants enjoy constant levels of income and expenditure, albeit at somewhat unjust levels (but at smaller levels of inequality, with associated disputes over what constitutes a “just” level, than pervade in many societies). In terms of numbers: assuming a total annual wage income in the South and North of 200 MU and 800 MU, respectively, the distortion in household income associated with a southern budget deficit of 10% is +5% in the South and −1.25% in the North. Can this imbalance be corrected without a major disruption of the economy?

We consider two readjustment scenarios, immediately implemented after the first four years. In scenario 1, the southern government budget deficit is immediately balanced, accompanied by full debt forgiveness. In scenario 2, the budget deficit of 10% is converted to a surplus of 4%, leading to a complete repayment of the debt after about 14 years.

For both scenarios, we consider a number of alternative outcomes a, b, c, d, dependent on the assumed actions of firms and banks (Table 1, Figure 3). In scenarios 1a and 2a, a perfect-market response is assumed: the reduced demand of southern households induces firms to reduce prices to clear the market. There is no impact on employment; incomes and consumption sim-
Table 1: Alternative responses to southern budget adjustment.

<table>
<thead>
<tr>
<th></th>
<th>a</th>
<th>b</th>
<th>c</th>
<th>d</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: balanced budget</td>
<td>perfect market, full employment</td>
<td>recession, high unemployment</td>
<td>—</td>
<td>green investments, low unemployment</td>
</tr>
<tr>
<td>2: debt repayment</td>
<td>perfect market, full employment</td>
<td>recession, higher unemployment</td>
<td>recession, reduced high unemployment</td>
<td>green investments, low unemployment</td>
</tr>
</tbody>
</table>

This economic-text-book picture is clearly not supported by the data. We accordingly discuss the impact of three alternative assumptions b, c, d regarding the response of firms, banks and governments to the budget readjustments. In scenarios 1b, 2b, the response of southern firms to the reduced demand is to lay off workers. This further reduces demand, resulting in still more lay offs. The vicious feedback cycle and resultant recession is halted only when wages have dropped sufficiently in response to the low employment level that the hiring of workers again becomes attractive.

Scenarios 2b and 2c differ in the assumed impact of the commitment of the southern government in scenario 2 to completely repay the debt, as opposed to scenario 1, in which the budget is merely balanced together with a complete debt forgiveness. In scenario 2b, it is assumed that this has no indirect impact. Thus the enhanced reduction in demand in the case of complete debt repayment simply leads to higher lay-off rates and a deeper recession. In scenario 2c, in contrast, it is assumed that the commitment to honour debt enhances the confidence of investors, promoting a higher willingness to invest. This more than offsets the initial stronger reduction in demand, leading to a weaker recession than in scenario 2b.

Scenarios 1d, 2d finally, represent the impact of government supported investments, for example, in renewable energy. This immediately promotes re-employment of workers laid off in response to the initial demand reduction following the government budget re-adjustment. In contrast to the slow
recovery from a recession, the recovery is no longer dependent on a prior wage reduction, but is made immediately attractive through government subsidies. This necessarily involves some form of redistribution in tax incomes and expenditures. However, with respect to the present focus on integrated flows and balances, this is immaterial. Relevant is only that a high level of employment is achieved, and that the employment is in activities that are conceived to have long-term benefits for society.

These concepts can be translated into a simple system of coupled first order differential equations (cf. Figure 1).

**Scenario 0**

The rate of growth of the southern government debt \( \text{govS} \) (held by the northern government \( \text{govN} \)) is given by

\[
d(\text{govN})/dt = \text{def} + \text{interest} \times \text{govN}
\]

where the interest rate \( \text{interest} = 0.04 \) and

\[
\text{def} = \text{bdgS} \times \text{reldef}
\]

is the absolute southern government budget deficit, defined by the nominal southern government budget \( \text{bdgS} = 100 \) MU and the fractional budget deficit \( \text{reldef} = 0.1 \).

The absolute southern government deficit \( \text{def} \) appears as a surplus purchase component \( \text{purchS} - \text{incomS} \) for southern households, which is then passed through, as indicated above (see Figure 1), as a surplus component to southern firms, northern firms, northern households and finally the northern government.

The resulting fractional enhancement of the household purchases (through underpayment of taxes) in the South, with a corresponding fractional reduction of household purchases in the North, is given by:

\[
(purchS - incomS)/incomS = \text{def}/incomS = 100 \times 0.1/(200 \times 0.95) \approx 0.05
\]

\[
(purchN - incomN)/incomN = -\text{def}/incomN = -100 \times 0.1/800 = -0.0125,
\]
where $\text{incom}_S = \text{wages}_S \times \text{empl}$, $\text{wages}_S = 200$ MU/year. The employment level in the South remains at its initial value $\text{empl}_0 = 0.95$ (regarded as the maximal effective employment level). Variations of employment in the North are ignored.

**Scenarios 1a, 2a**

These differ from scenario 0 through the replacement of the relative southern government budget deficit $\text{reldef} = 0.1$ in Eq. (2) for $t > 4$ years by $\text{reldef} = 0$ (scenario 1a, balanced budget) or $\text{reldef} = -0.04$ (scenario 2a, budget surplus). Formally, this is implemented (cf. Figure 1) through the definitions

\[
\begin{align*}
\text{reldef} &= \text{reldef}_0 \times (1 - \text{reddef}) - \text{reddef} \times \text{repay} \\
\text{reldef}_0 &= 0.1 \\
\text{reddef} &= \text{STEP}(1, T), \quad \text{where the function} \\
\text{STEP} &= \begin{cases} 
0 & \text{for } 0 \leq t \leq T = 4 \\
1 & \text{for } T < t
\end{cases} \\
\text{repay} &= \begin{cases} 
0 & \text{scenario 1a} \\
0.04 & \text{scenario 2a}
\end{cases}
\end{align*}
\]  

The modification again has no impact on employment, but the expressions (3), (4) for the fractional deviations in the household purchase levels relative to the scenario of a balanced southern budget now yield, instead of the previous values, Eqs. (3), (4) of scenario 0, for scenario 1a:

\[
\begin{align*}
\frac{(\text{purch}_S - \text{incom}_S)}{\text{incom}_S} &= \frac{\text{def}}{\text{incom}_S} = 0
\end{align*}
\]

\[
\begin{align*}
\frac{(\text{purch}_N - \text{incom}_N)}{\text{incom}_N} &= \frac{\text{def}}{\text{incom}_N} = 0
\end{align*}
\]

and for scenario 1b

\[
\begin{align*}
\frac{(\text{purch}_S - \text{incom}_S)}{\text{incom}_S} &= \frac{\text{def}}{\text{incom}_S} \\
&= -100 \times 0.04/(200 \times 0.95) \approx -0.02
\end{align*}
\]

\[
\begin{align*}
\frac{(\text{purch}_N - \text{incom}_N)}{\text{incom}_N} &= \frac{-\text{def}}{\text{incom}_N} \\
&= 100 \times 0.04/800 = +0.005
\end{align*}
\]
Scenarios 1b, 1c, 2c

In the previous scenarios 0, 2a and 2b, the stocks-and-flows balances were limited to firms, households and governments, i.e. to the six top-right boxes of Figure 1. Banks were not involved, and the (southern) employment level entered only as a constant value $\text{empl}_0 = 0.95$. In the following scenarios 1b, 1c, 2c representing the recession scenario, the set of actors is extended to include banks, represented by the variable $\text{cap}$, and the employment level $\text{empl}$ now becomes a time dependent state variable determined by the integral of the difference between hiring and firing workers.

The budget adjustment implemented at time $t=4$ years has two direct impacts: it reduces the total purchasing power $\text{purchS}$ in the South through increased taxes and reduced government social support, and it reduces both $\text{purchS}$ and the employment level $\text{empl}$, if government workers are laid off. In the previous perfect-market scenarios 1a, 2a, rapid recovery of the government employment level was assumed through price adjustments, so that only the reduction in purchasing power was considered. If the previously computed reduction in total southern purchasing power relative to the solution Eq. (3) for a constant budget deficit had been expressed instead in terms of an equivalent reduction in employment level, retaining the individual purchasing power of employed workers, the relative changes in the southern employment levels would have been $-5\%$ (scenario 1a) and $-7\%$ (scenario 1b). This is a relatively minor effect compared with the predictions for the recession model discussed below. To avoid introducing too many model parameters, we therefore neglect in the following the direct impact on the employment level of released government employees compared with the workers laid off by firms (although the effect can be readily incorporated through the inclusion of a direct government-induced step-function component in the computation of the employment level, Eqs. (14)-(16)).

The rate of change of the employment level is given by the difference between the hiring and firing of workers:

$$d(\text{empl})/dt = \text{hiring} - \text{firing} \quad (14)$$

where we have set

$$\text{hiring} = \beta \times \text{cap} \times (\text{empl}_0 - \text{empl}) \quad (15)$$

$$\text{firing} = \alpha \times (\text{reldef}_0 - \text{reldef}) \times \text{empl} \quad (16)$$

with constants $\alpha = 4 \text{ [year}^{-1}]$, $\beta = 0.001 \text{ [MU}^{-1}\text{year}^{-1}]$. The new variable $\text{cap}$ represents the capital provided by banks for the creation of jobs. It is
assumed that, given \(\text{cap}\), the rate of creation of jobs is proportional to the effective unemployment factor \((\text{empl}0 - \text{empl})\): the higher the unemployment factor, the lower the wages, and the more attractive the creation of jobs.

We assume that for all three scenarios 1b, 2b and 2c, the capital available for the investment is governed by the same differential equation

\[
d(\text{cap})/dt = \gamma \times (\text{empl}0 - \text{empl})
\]

(17)

with a constant \(\gamma = 1000\ [\text{MU/year}]\), the factor \((\text{empl}0 - \text{empl})\) expressing again the increase in the willingness of banks to provide capital to create jobs when the employment level and wages are high.

The distinction between scenarios 1b, 2b and 2c arises through the choice of the initial value \(\text{cap}0\) of the available capital. In scenarios 1b, 2b, it is assumed that the banks have low confidence in the ability of the southern government to fulfill its debt restructuring commitment. Thus the initial value is set as \(\text{cap}0 = 0\). In scenario 2c, in contrast, the intention of the southern government to completely repay its debt rather than requesting a debt cancellation is interpreted as an expression of serious reform, increasing the trust of investors. The initial value of the available capital is accordingly set as \(\text{cap}0 = 500\ \text{MU}\).

The resultant employment curves for the alternative assessments 2b and 2c of the complete-debt-repayment scenario 2 bracket the employment curve 1b for the balanced-budget scenario 1. However, independent of details, all three scenarios represent serious recessions resulting from the laying off of workers in response to the reduced demand created by the government austerity policy, with the associated destabilizing feedback of further reductions in demand produced by the decreased employment.

**Scenarios 1d, 2d**

Keynes argued already in his fundamental 1936 analysis following the Great Depression that the inherently unstable demand-employment feedbacks of an unregulated economic system need to be balanced by counter-cyclic government investment policies. These are included in scenarios 1d, 2d in the form of an additional source \(\text{grncap}\) of capital representing government sponsored investments in renewable energy.

The rate of growth of green capital and the impact of \(\text{grncap}\) on the rate of hiring is assumed to be the same as that of normal capital. The only
Table 2: Model constants; not listed are the zero initial values $\text{gov}S0, hS0, \text{fm}S0, \text{fm}N0, \text{hs}N0, \text{gov}N0$. Units are in MU and years.

difference lies (as before in the case of scenarios 2b, 2c) in the initial value of the available capital, which is now set at $\text{greencap}0 = 3000$. The significantly higher level of initially available green capital reflects the assumed joint North-South commitment to a green Marshall plan, independent of the reduction in demand that depressed the initial values $\text{cap}0$ in scenarios 1b, 2b, 2c. The higher levels of investment results in significantly higher employment levels for scenarios 1d, 2d (Figure 3).

Summary

Our model has focussed on processes. Units were specified only in terms of orders of magnitude, with no attempt at a calibration with respect to some particular country or set of countries involved in the euro crisis. The purpose of the model was to identify the dominant processes and their interaction in order to understand the impacts of alternative policies — clarifying at the same time the assumptions underlying the inferred policy impacts. This we have attempted at the mental-model level that has characterized the current euro crises debate.

As in all models, the question arises whether the inferred conclusions are reasonably stable with respect to: a) the values of the model constants (Table 2) and parameters (Table 3); b) possible alternative interpretations and representations that yield similar predictions; and c) extensions to a more sophisticated model including other important processes, including, in particular, the redistribution of taxes and subsidies involved in the implementation of a Green Marshall plan.

With respect to a), our model is indeed stable: small deviations of the model parameters lead to comparable small deviations of the predictions. With respect to b), we could indeed have simultaneously chosen different values for two or more parameters to yield essentially the same prediction. Thus instead of choosing a significantly larger value for the initial green capital than for initial normal capital, we could have chosen the same initial values but
have replaced instead the constant $\beta$ by a higher constant for the employment impact of green capital. This would have yielded a similar employment impact of green capital. However, we regard this not as a basically different model. We assume in both cases that green capital has a significantly larger impact on employment than regular capital, as its availability is not deterred by the breakdown of demand following the budget readjustment.

Finally, the modifications of our conclusions through a carbon tax or subsidies for renewable energy, that must necessarily accompany government support for a green transformation, have not been explored. However, we anticipate that our principal conclusions will not be affected. Past experience regarding government supported investments in renewable energy points always to an increase in employment. A more sophisticated treatment of the financial sector than our simple two-bank model is also not expected to affect our basic stocks-and-flows arguments.

The basic advantage of a simple actor-based, system-dynamic model is that alternative assumptions regarding actor behaviour and the assumed system response can be readily implemented and tested. The model runs about one second on a lap-top, and the model implementation of the six alternative policy scenarios presented could easily have been carried out in real time in the course of a policy-maker debate on the optimal resolution of the euro crisis.

We argue that such modelling tools should be more widely applied to bring the question of climate change mitigation into the focus of policy makers faced with other important societal problems.

The North-South Euro crisis model can be downloaded from the MADIAMS webpage at the Global Climate Forum website (http://www.globalclimateforum.org/madiams).

Table 3: Scenario-dependent parameters. Units are in MU and years.
Figure 1: **Stocks-and-flows sketch (Vensim® DSS) of interactions between banks, firms, households and governments in a North-South euro crisis model, including normal investments and investments in a Green Marshall Plan.**
Figure 2: Evolution of southern government debt. Scenario 0: a constant budget deficit of 10%; Scenario 1: a balanced budget after four years; Scenario 2: a budget surplus of 4% after four years, leading to full debt repayment near year 18.
Figure 3: Evolution of southern employment for scenarios 1a (constant budget deficit), 1b (balanced budget, recession model), 2b (debt repayment, recession model), 2c (debt repayment, recession model with increased trust), 1d (balanced budget, green investments) and 2d (debt repayment, green investments).