

Report on Cockshott P. and Zachariah D. paper about
"Conservation laws, financial entropy and the Eurozone crisis".

This paper is interesting in several aspects, certainly for the use of some Physics notions to the understanding of economic phenomena but, I think, there is more than this. Therefore, with this report, I would like to transmit to readers the flavour of the paper, why it should deserve their attention and how the authors can improve their exposition. I have read the paper with deep interest, therefore, I propose my analysis highlighting points of weakness and strength, at least to my understanding. I hope my contribution will help the authors, for further developments, and the readers, for an easier comprehension.

The paper is well written and it is structured in four parts. On the basis of the underlying phenomenological theory, the authors' effort in developing an interpretative framework to work out analytic tools for the comprehension of economic phenomena is remarkable. The bibliography is coherent and suitable, even though I was surprised for not seeing a reference to the work of Nicholas Georgescu-Roegen, mainly to Roegen (1960).

Having went through the paper, and by using the suggested bibliography, I express my appreciation for the work done but I would also point out some overall remarks. The paper contains some generalisations mainly deducible on the ground of the underlying theory, and on previous studies the authors have made, it takes to wait for the third and fourth sections to find a comparison to some real data. The paper is original and primary but, even though verbally well developed, there are parts in which, as a reader, I felt just like having the intuition of deductions' meaning without being certain of having properly understood their implications. Deductions and interpretations, although as likely as shareable, are spread though the paper and there is not a conclusive section in which the flow of the found results replicates the structure of the research to explain why the proposal is relevant. The reader is left alone in doing this. The stylistic choice of the authors was to highlight their findings step by step. In principle there's nothing wrong with this, but the risk is that, once the reading has finished, a few of the results remain in readers' mind. Furthermore, since some of them could have been argued differently, mainly in the third and fourth sections, one may be tempted to ask herself the following: (a) what is the relevance of the first two sections in showing that an exchange economy is analogue to a conservative system while a 'financialised' market economy is not; (b) what is the need to refer to the Marxian motion laws of capitalism; (c) what is the need to highlight so many contradictions in the capitalistic way; (d) why should one involve Physics to show the theoretical consistence of Marxian thought against the contradictory capitalist mode. It is my opinion that a lot of the added value of the paper, and of its strength points, is in answering more explicitly to questions like these to shed more light on the topics of the third and fourth sections. I feel like the answers have already been implicitly given by authors, but a more explicit recapitulation would be useful. All in all, I would have appreciated reading an 'introduction with motivations', to figure out the field, and a final section of 'conclusive remarks', to summarise the main findings.

After this I would like to discuss what seems to be a limitation of this paper: a logically coherent theoretical phenomenology (see sections 1 and 2) has been carefully applied to real world problems (see sections 3 and 4) by means of analogy but without the same care about the ontology for bodies and observables. I think this is important since the authors chose to involve some notions drawn from Physics (i.e. system, phase-space, entropy, free energy). I am not sure the analogy has been always made properly because of a lack of ontology: (a) on page 5 the authors set an analogy between the mass of a particle and the financial position of a firm on a phase-space, so implicitly assuming the mass is one of the degrees-of-freedom; (b) formulae (1) and (2) on page 5 and 6 are used to explain conservation laws for system's observables totals but they seem more like constraints on their expected values; (c) on page 7 they introduce the notion of financial-entropy: it is not so clear why it should be always growing, except in the provided example; (d) on page 13 they draw an analogy between the

'work' done by credit and the free energy by means of the (financial) entropy increase. All these analogies are foundational of the model but they are not so easy to be understood beyond the level of the intuition. I hope these overall comments will be useful for the authors and intriguing for potential readers.

Now I would like to describe the structure of the paper. In Section 1, according to Marx's Capital 'mechanics', some analogies are made with Classical Mechanics and the notion of 'equivalence relation' for the commodity exchange in a system driven by conservation laws is developed. The notions of phase-space and financial-entropy are introduced, together with the free energy, to prepare an interpretative model for exchange economies showing that the notion of conservative systems is analogue to the mechanics of commodity exchange. This section ends up with a main result: money introduces a formal value against the real value of commodities, which is the value of labour embedded into goods, and that the two notions of value are contradictory. This section (and the following) is important because, beyond the critique I have moved so far, it seems to be on a right way to melt economic theory with formal tools.

Section 2 deals with non-conservative principles by introducing the basic law of motion of the capitalistic system: production surplus is extrapolated from labour to gain profits. It is interesting the way the authors explain how profits must be the effect of something which is originating from outside of the production system. Several other topics are developed but two main deductions are worth stressing: (a) the capitalistic system, by nature, is facing some constraints it cannot overcome alone; (b) there are some intrinsic contradictions which should set its breakdown. The first constraint concerns the profitability (the authors refer to an index they developed in the cited references, see eq. (7) on page 19) which is linked to demographic factors and the scarcity of resources. Moreover, the authors do not only consider limitations for inputs to the capitalistic mechanics but also for its output, which concerns emission constraints and related effects. The Marx's motion law of capitalistic system is explained and confronted with some contradictions intrinsic to the exponential growth driving the capital accumulation.

Section 3 explains why market exchange and capital accumulation are so contradicting one another. The reasoning is based on the monetary system's transformations in history, before discussing what might be seen as the core problem: the formation of interest. This leads the reader to the dynamics of sector balances almost naturally, to conclude that "Short of such spectacular growth rates, rapid capital accumulation is unsustainable in the capitalist sector and a substantial portion of profits will instead be accumulated as financial surpluses and spent on luxury consumption", see page 34.

The crisis of the Eurozone is the topic of the last section. The main tool here involved is the average profitability equilibrium index developed in Section 2 (see Figure 10) and the authors focus their attention on the Stability Pact. They analyse the effects of the implications of the pact, when facing austerity, on different sectors (households, firms, governments and the World outside Europe). The conclusion is drastic: "Any serious attempt to impose balanced budgets (the authors refer to conservation laws developed in the first two sections) by austerity measures will be ineffective in its professed aim, and would as a side effect engender a downward spiral of bankruptcies, rising unemployment and deepening economic ruin", see page 40.

As it might be understood the paper is full of insights. Although some points may seem obscure at a first sight, the authors' effort to explain their thought with theoretical and historical examples is self-evident.

Bibliography

Roegen, N.G., (1960), "Mathematical proofs of the breakdown of capitalism", *Econometrica*, 28(2), pp.225-243.