Reply to referee report 1 (December 11 2017; 15:34)

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Comment 1

We do not see the relevance of the comment. A double entry accounting is a system that describes and keeps track on economic actions. It does neither make claims nor require a certain micro theory of economics. In our paper we present a micro theory of economics that consist of various heterogeneous interacting agents that make economic actions with each other. If one wishes to make double accounting with our heterogeneous agents (and form for all of them the income statement and the balance sheet), it is possible. It is not possible to derive from principles of double entry accounting the principles of our micro theory (i.e., the economic forces). Thus this work has not been done by Luca Pacioli in 1495 – if it were, then Luca Pacioli would also have invented the modern differential calculus and would be an unknown authority in the field of physics, the inventor of dynamics, which is generally attributed to Isaac Newton.

Comment 2

The remarks presented here do not prove our proposal of economic forces wrong. A few remarks, especially concerning the referee's claim ”*In companies with profits, $Y - C = S$, capital grows after each cycle by the surplus (S). Since capital is not constant, Newton's mechanics is invalid. Companies that generate profit are like systems producing heat; economic laws correspond to the laws of thermodynamics, like in (c). [1, 2].*”:

- It is a well-known fact among physicists that, i.e., the second ”law” of thermodynamics is not a lawlike principle that the nature always obeys, but only a statistical generalisation resulting from the assumption of ”Stosszahl Ansatz” (assumption of molecular chaos).
- In statistical mechanics the Stosszahl Ansatz is one way to derive from a micro theory of gases (Newtonian mechanics) some thermodynamic macro results, e.g., the second ”law” of thermodynamics via Boltzmann H theorem.
- Stosszahl Ansatz is problematic:
  > *It means that the collision probability is directly proportional to the product of the particle densities in a phase-space element. Generally, assuming Stosszahl Ansatz is valid in the thermodynamic limit (the particle number and the volume are infinite, but the density is finite), but a lot of information about the dynamics of the system is discarded in assuming it.* [3]
- The underlying micro theory behind (classical) thermodynamics is classical (Newtonian) mechanics. Thus, in economics, if a macro theory corresponds to thermodynamics, then by analogy the underlying micro theory in economics is Newtonian. If there is no derivation yet of how Newtonian economics results in thermodynamic economics that the referee is keen on, it is not our fault but a future research topic. We stress that in physics there is no contradiction between classical mechanics as a micro theory and thermodynamics as a macro theory.

In response to remark (c): ”Systems with frictional forces generate heat and do not conserve mechanical energy; these systems follow the laws of thermodynamics.”

- Friction is a generalisation of multi body collisions and interactions. It is possible to reduce it into many particle interactions and thus describe it within classical mechanics.
- Moreover, in statistical mechanics, it is a well known fact that the heat of a gas is the kinetic

movement of the gas molecules. The more heat, the greater velocities of gas molecules. Thus, from the micro theory point of view there is no stark contrast between the mechanical energy and heat.

General

Moreover, we find baseless the proposal of the referee to rename our article as "A dynamic theory of economics without economic growth". First of all, we stress that our equations and simulation model are so flexible that the standard economic growth via technical advances can be implemented into our equations as, e.g., with time dependent parameters of the cost function. In the first approximation, we have not done it. Second, model-theoretically our simulation model is an open system, i.e., the money earned by consumers comes from outside as well as the interest earnings, and interest payments and costs of firms go outside the system. This openness results in that there is economic growth from time to time and there are economic contractions as well, as seen in our figure that represents GDP.

If readers are more interested in theoretical questions concerning relations between micro and macro theories, discussion about reversible classical mechanics that yields in irreversible thermodynamics within classical statistical mechanics concerning entropy, and in quantum physics concerning coherence, the reader is encouraged to study the dissertation thesis of the corresponding author [3]. There also exists a splendid book by Lawrence Sklar that stresses the philosophical questions concerning statistical mechanics, thermodynamics and reversible classical mechanics [4].

Referee's references

[1] Yakovenko, V. M. & J. B. Rosser, J. B. (2009) Colloquium: Statistical Mechanics of Money, Wealth and Income, Rev. Mod. Phys. 81, 1703
[2] Mimkes, J., (2006) A thermodynamic formulation of economics, in Econophysics & Sociophysics: Trends & Perspectives, Chakrabarti, B. K., Chakraborti, A. & Chatterjee, A. (Eds.), WILEY-VCH, Germany

Our references

[3] Alia Dannenberg, *On the fundamentals of coherence theory*, Helsinki Institute Physics Internal report series HIP-2011-02, Yliopistopaino (2011) http://urn.fi/URN:ISBN:978-952-10-5328-3
[4] Lawrence Sklar, *Physics and Chance: Philosophical Issues in the Foundations of Statistical Mechanics*, Cambridge University Press (1993).