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Analysis

Coping With Collapse: A Stock-Flow Consistent Monetary Macrodynamics of Global Warming

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ABSTRACT

This paper presents a macroeconomic model that combines the economic impact of climate change with the pivotal role of private debt. Using a Stock-Flow Consistent approach based on the Lotka–Volterra logic, we couple its nonlinear monetary dynamics of underemployment and income distribution with abatement costs. A calibration of our model at the scale of the world economy enables us to simulate various planetary scenarios. Our findings are threefold: 1) the +2 °C target is already out of reach, absent negative emissions; 2) the long-term (resp. short-term) results of climate change on economic fundamentals may lead to severe economic consequences without the implementation (resp. in case of too rapid an application) of proactive climate policies. Global warming (resp. too fast transition) forces the private sector to leverage in order to compensate for output and capital losses (resp. to lower carbon emissions), thus endangering financial stability; 3) Implementing an adequate carbon price trajectory, as well as increasing the wage share, fostering employment, and reducing private debt make it easier to avoid unintended degrowth and to reach a +2.5 °C target.

1. Introduction

Given the increasing awareness of climate disturbance, which crystallized at a diplomatic level in the Paris Agreement of December 2015, and the growing concern about potential downside consequences of a temperature increase, the question is raised of whether global warming might *per se* destabilize the world economy. This paper contributes to this issue and sheds some light on one way to avoid this threat by relying on a carbon price mechanism set by the regulator. More particularly, according to the Paris Agreement, 195 countries pledged to reach net zero emissions in the second half of this century.

Yet, beyond the bio-physical issue of warming, the financial stake of the cost of mitigation and adaptation should not be neglected either. According to the New Climate Economy Report (2014), US$ 90 trillion are needed at the world level over the next 15 years to fund clean infrastructure that would make it possible to reach zero net emissions, which prompts a pressing question: how will the world economy finance such monetary flows? Given today's vulnerability of public finances, it is expected that the private sector will be able to endorse the much needed long-run investments. This, in turn, raises a new question: will the world economy be able to carry the corresponding additional private debt burden?[1] As argued by Bank of England Governor Mark Carney (Carney, 2016), too rapid a movement towards a low-carbon economy could materially damage financial stability.

Taking advantage of a growing body of literature in ecological macroeconomics —see, for instance, Barrett (2018), Dafermos et al. (2017), Dietz and Stern (2015), Jackson (2009), Nordhaus and Sztorc (2013), Rezai and Stagl (2016), Rezai et al. (2018, 2013)—, we present an integrated ecological macroeconomic model that combines two sources of instability: (i) global warming and (ii) private over-indebtedness. By incorporating the latter into a rather low-dimensional stock-flow consistent integrated assessment model (hereafter IAM), we are able to track transmission channels between the two sources of potential economic vulnerability alluded to by Carney. As already made

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[1] See Giraud (2017) for a first grasp of this issue.

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clear by Nordhaus (2016) among others, the $+2^\circ$ C target seems already to be out of reach absent carbon sequestration. That is why we discuss carbon pricing trajectories that succeed in avoiding a severe recession by implementing a feasible cap on global warming that does not necessarily remain below $+2^\circ$ C.

The paper is organized as follows. Section 2 briefly links our stock-flow consistent model with the background literature on IAMs. Section 3 sets up the modeling framework. Section 4 provides some first mathematical insights into the destabilizing impact of climate change on our modeling. Section 5 addresses this interplay more extensively and numerically through an analysis of three prospective scenarios. Section 6 discusses the deployment of a public policy instrument—a carbon price—that may help cope with the possible climate and financial disasters that emerge from the analysis in the previous sections. Our main conclusions and areas for future research are outlined in the final section.

2. Alternative Modeling Foundations

Over the past thirty years, many IAMs have been developed to estimate the impact of economic development on the environment. A solid body of literature compares IAMs, describing their advantages and disadvantages, e.g., Schwanitz (2013). The models considered in this literature usually involve macroeconomic settings that rely on welfare maximization, general equilibrium, partial equilibrium and cost minimization (Stanton et al., 2009). For instance, the core economic model of the DICE model of Nordhaus (1993), the benchmark for IAM literature, is the Ramsey–Cass–Koopmans approach. It assumes a closed economy endowed with a constant return to scale Cobb–Douglas technology combining labor and capital, where agents' decisions are made under perfect foresight. At the steady state, output increases at the pace of labor force growth and technological progress while factor costs adjust such that all markets clear. By construction, such a dynamics precludes situations such as mass unemployment and over-indebtedness.

By contrast, recent research has contributed to building alternatives to such IAMs by incorporating Keynesian features (see, e.g., Barker et al., 2012) or more post-Keynesian insights (see, e.g. Dafermos et al., 2017). Our modeling approach does not assume fully optimal behavior either. Instead, it relies on the ideas of Hyman Minsky on the intrinsic instability of a monetary market economy, which have experienced a significant revival in the aftermath of the 2007–2009 financial crisis. We adopt a mathematical formalization of Minsky's standpoint to assess the role of private debt dynamics in our narrative.[2] Our starting point is the prey-predatory macrodynamics first introduced by Goodwin (1967) and Akerlof and Stiglitz (1969), and later extended by Keen (1995). Building on this insight, we offer a model based on the myopic behavior of imperfectly competitive firms, which is stock-flow consistent (Godley and Lavoie, 2012), allows for multiple long-run equilibria, and exhibits endogenous monetary cycles, sticky prices, endogenously determined private debt, and underemployment. Moreover, money is endogenously created by the banking sector (Giraud and Grasselli, 2017). Here, by contrast with more conventional general equilibrium approaches, the current state of the economy may be already following a path leading to a future severe economic recession if no shift away from a business-as-usual scenario is implemented.[3]

[2] Dos Santos (2005) provides a survey up to 2005 of the literature on the modeling of Minskian instability; more recent contributions include Ryoo (2010) and Chiarella and Di Guilmi (2011).

[3] Dietz and Stern's (2015) extension shows that the DICE model can also exhibit output trajectories characterized by a severe economic recession, as does the model introduced in this paper. In addition, however, we characterize such recessive paths in terms of mass unemployment and private over-indebtedness — which are difficult to obtain in the DICE equilibrium model.

3. An Integrated Framework

Our IAM depicts the interrelations between a global monetary economy and climate change. Although, for simplicity, the public sector is not explicitly modeled, public policy objectives are materialized through the deployment of a carbon price that allows a decentralized emission reduction rate to be achieved.[4] The core macroeconomic module is presented in Subsection 3.1 and the climate module is detailed in Subsection 3.2. The introduction of damages and the way these can be controlled through public policy objectives is discussed in Subsection 3.3. The empirical calibration of the IAM is provided in Appendix E.

3.1. The Monetary Macrodynamics

Our macroeconomic model belongs to the literature centered around Keen (1995).[5] One appeal of this framework lies in its ability to formalize long-term economic deflation and degrowth as a consequence of over-indebtedness.

3.1.1. Damaged Production and Abatement

The productive sector produces a real amount, Y^0, of a unique consumption good combining labor and capital:

$$Y^0 = \frac{K}{\nu} = aL, \tag{1}$$

where K and L refer respectively to the stock of capital and labor, while ν and a stand respectively for the (constant) capital–output ratio and Harrod-neutral labor-augmenting technological level. For simplicity, full capital use is assumed and Say's law is postulated.

As defined shortly, economic activities release CO_2-e emissions that will be priced through a carbon pricing instrument (carbon tax). As an answer to the tax burden, the productive sector may engage in abatement activities to lower its CO_2-e emissions. By doing so, a fraction, A, of output, Y^0, is diverted from its final use, and serves instead as an intermediate consumption in order to reduce CO_2-e emissions as defined shortly. Moreover, as in Nordhaus (2007), a proportion $\mathbf{D}^Y$ of the remaining output is damaged beyond repair by global warming and lost. Consequently, the production available on the commodity market is given by

$$Y: =(1-\mathbf{D}^Y)(1-A)Y^0. \tag{2}$$

3.1.2. Profits, Investment and Inflation

Let us denote by p the consumption price, Π, the nominal net profit, w, the unitary money wage, r, the short-term interest rate[6], L_c, the total amount of corporate debt, M_c, the deposits held by the productive sector, p_c, the real price of a ton of CO_2-e expressed in 2010 US\$, E_{ind}, the volume of industrial emissions in GtC, to be defined shortly, and $\delta > 0$ the standard depreciation rate of capital. Nominal profit, Π, is defined as the nominal output *minus* production cost:

$$\Pi: =pY - wL - rD - pT_f - p\delta_{\mathbf{D}}K. \tag{3}$$

The cost of production is the sum of: (i) the wage bill, wL; (ii) the private debt burden—where $D := L_c - M_c$ stands for the outstanding balance of current nominal private debt; (iii) the payment of the carbon tax, $pT_f := pp_C E_{ind}$; and (iv) the global depreciation rate of capital, $\delta_{\mathbf{D}} := \delta + \mathbf{D}^K$, where $\mathbf{D}^K$ is the rate of degradation induced by climate

[4] Public intervention, as well as the resulting dynamics of public debt are left for future research.

[5] Such as Grasselli and Lima (2012),Grasselli et al. (2014), Nguyen-Huu and Costa-Lima (2014), Grasselli and Nguyen-Huu (2015b) and Giraud and Grasselli (2017) *inter alia*.

[6] For simplicity, r is kept constant here. Endogenous short-run interest rate is left for future research.