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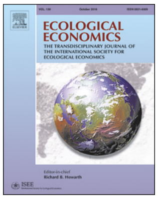

Analysis

Climate Change, Financial Stability and Monetary Policy

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ABSTRACT

Using a stock-flow-fund ecological macroeconomic model, we analyse (i) the effects of climate change on financial stability and (ii) the financial and global warming implications of a green quantitative easing (QE) programme. Emphasis is placed on the impact of climate change damages on the price of financial assets and the financial position of firms and banks. The model is estimated and calibrated using global data and simulations are conducted for the period 2016–2120. Four key results arise. First, by destroying the capital of firms and reducing their profitability, climate change is likely to gradually deteriorate the liquidity of firms, leading to a higher rate of default that could harm both the financial and the non-financial corporate sector. Second, climate change damages can lead to a portfolio reallocation that can cause a gradual decline in the price of corporate bonds. Third, climate-induced financial instability might adversely affect credit expansion, exacerbating the negative impact of climate change on economic activity. Fourth, the implementation of a green corporate QE programme can reduce climate-induced financial instability and restrict global warming. The effectiveness of this programme depends positively on the responsiveness of green investment to changes in bond yields.

1. Introduction

Climate change is likely to have severe effects on the stability of the financial system (see, for instance, Aglietta and Espagne, 2016; Batten et al., 2016; Scott et al., 2017). Two broad climate-related financial risks have been identified: (a) the *transition risks* that have to do with the re-valuation of carbon-intensive assets as a result of shocks related to the transition to a low-carbon economy; and (b) the *physical risks* that are linked to the economic damages of climate-related events. So far, most studies have concentrated on the implications of transition risks (see e.g. Carbon Tracker Initiative, 2011; Johnson, 2012; Battiston et al., 2017; Stolbova et al., 2018; Trinks et al., 2018). Less attention has been paid to the detailed analysis of physical risks, which have only partially been explored in macro models by Dietz et al. (2016), Dafermos et al. (2017) and Bovari et al. (2018). The investigation of the physical risks is particularly important: it would help us understand how the financial system could be impaired if the transition to a low-carbon economy is very slow in the next decades and, consequently, severe global warming is not ultimately avoided. It would also allow us to understand which policies might be more effective in reducing the financial instability that might stem from climate damages.

In this paper, we develop an ecological macroeconomic model that sheds light on the physical effects of climate change on financial stability. This is called the DEFINE (Dynamic Ecosystem-FINance-Economy) model, which builds on the stock-flow-fund model of Dafermos et al. (2017). The latter relies on a novel synthesis of the stock-flow consistent (SFC) approach of Godley and Lavoie (2007) with the flow-fund model of Georgescu-Roegen (1971, ch. 9; 1979, 1984).[1] The model is calibrated and estimated using global data and simulations are presented, which illustrate the effects of climate change on the financial system. We pay attention to the following key channels. First, the increase in temperature and the economic catastrophes caused by climate change could reduce the profitability of firms and could deteriorate their financial position. Accordingly, debt defaults could arise, which would lead to systemic bank losses. Second, lower firm profitability combined with global warming-related damages can affect the confidence of investors, inducing a rise in liquidity preference and a fire sale of the financial instruments issued by the corporate sector.

Dietz et al. (2016) have recently investigated quantitatively the physical impact of climate change on the financial system. They use a standard integrated assessment model (IAM) and the climate value at risk (VAR) framework. Assuming that climate change can reduce the dividend payments of firms and, hence, the price of financial assets, they provide various estimates about the climate-induced loss in the

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[1] See the model's website: www.define-model.org.

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value of financial assets. Our study moves beyond their analysis in three different ways. First, by relying on an SFC approach, we portray explicitly the balance sheets and the financial flows in the financial sector. This allows us to model the climate-induced fragility that can be caused in the financial structures of firms and banks, a feature which is absent in Dietz et al. (2016). Second, we utilise a multiple financial asset portfolio choice framework, which permits an explicit analysis of the climate-induced effects on the demand of financial assets in a world of fundamental uncertainty. This allows us to capture the implications of a fire sale of certain financial assets. These implications are not explicitly considered in the model of Dietz et al. (2016) where climate damages do not have diversified effects on different financial assets. Third, the financial system in our model has a non-neutral impact on economic activity: credit availability and the price of financial assets affect economic growth and employment. Accordingly, the interactions between economic performance and financial (in)stability are explicitly taken into account. This is crucial since the feedback economic effects of bank losses and asset price deflation can exacerbate climate-induced financial instability (see Batten et al., 2016). On the contrary, Dietz et al. (2016) utilise a neoclassical growth framework where long-run growth is independent of the financial structure of firms and banks. This leaves little room for the analysis of the macroeconomic implications of climate-induced financial problems.

Our methodological approach shares more similarities with Bovari et al. (2018) who have investigated how climate change can affect the indebtedness of firms, using an SFC model. However, their model abstracts from asset prices and assumes a passive banking system in which there is no explicit credit rationing and no effect of endogenous defaults on bank capital. This implies that the feedback effects of climate-inducing financial instability on the macroeconomy cannot be explicitly explored, as is the case in the current model.

Our simulation results illustrate that in a business as usual scenario climate change is likely to have important adverse effects on the default of firms, the leverage of banks and the price of financial assets. These effects become more severe after global warming passes the 2.5 °C threshold. Importantly, climate-induced financial instability reinforces the adverse effects of climate change on economic activity.

An additional contribution of this paper is that it examines how monetary policy could reduce the risks imposed on the financial system by climate change. Drawing on the recent discussions about the potential use of monetary policy in tackling climate change (see e.g. Murphy and Hines, 2010; Werner, 2012; Rozenberg et al., 2013; Anderson, 2015; Barkawi and Monnin, 2015; Campiglio, 2016; Matikainen et al., 2017; Volz, 2017; Monasterolo and Raberto, 2018), we examine the extent to which a global green quantitative easing (QE) programme could ameliorate the financial distress caused by climate change. This programme involves the purchase of green corporate bonds.

The paper's outline is as follows. Section 2 presents the structure of the model and the key equations that capture the links between climate change, financial stability and monetary policy. Section 3 describes the calibration, estimation and validation of the model. Section 4 analyses our simulations about the effects of climate change on the financial system. Section 5 focuses on the impact of a green QE programme. Section 6 concludes.

2. The Model

The DEFINE model (version 1.0) consists of two big blocks: (i) the ‘ecosystem’ block that encapsulates the carbon cycle, the interaction between temperature and carbon, the flows/stocks of energy and matter and the evolution of ecological efficiency indicators; (ii) the ‘macroeconomy and financial system’ block that includes the financial transactions, the balance sheet structure and the behaviour of households, firms, banks, central banks and the government sector. The technical description of the model and the information about the data used for its calibration and estimation can be found in Appendix A.

It is assumed that there is one type of material good that can be used for durable consumption and (conventional and green) investment purposes. Four matter/energy transformation processes are necessary for the production of this good and all of them require capital and labour. First, matter (non-metallic minerals and metal ores) has to be extracted from the ground and has to be transformed into a form that can be used as an input in the production. Second, useful energy has to be generated based on non-renewable sources (e.g. oil, gas and coal) or renewable sources (e.g. sun, wind). Third, recycling has to take place. Every year a part of the capital stock and the durable consumption goods that have been accumulated in the socio-economic system are demolished/discarded; the material content of these accumulated capital goods and durable consumption goods is called socio-economic stock.[2] A proportion of this demolished/discarded socio-economic stock is recycled and is used as an inflow in the production of the final good. This means that not all of the matter that is necessary for the production of the good has to be extracted from the ground. Fourth, the final good needs to be produced using material and energy inflows from the other processes.

Crucially, all these four processes, in combination with the functioning of the whole socio-economic system, generate by-products. In particular, industrial CO_2 emissions are produced as a result of the combustion of fossil fuels. Energy is dissipated in all transformation processes; this energy cannot be used again. In addition, the demolished/discarded socio-economic stock that is not recycled becomes waste. Part of this waste is hazardous and can have adverse effects on the health of the population.

Since the model focuses on the aggregate effects of production, all the above-mentioned processes have been consolidated and are presented as part of the total production process. An unconsolidated formulation of the production process would make the model and its calibration much more complicated without changing the substance of the analysis that we pursue here. However, such an unconsolidated version would be useful for the analysis of intra-firm dynamics and could be the subject of future extensions of the model.

Although capital, labour, energy and matter are all necessary in the transformation processes, these resources do not directly determine the level of production as long as they are not scarce: in the absence of scarcity, the level of production is demand-determined, in line with the post-Keynesian tradition. However, if any of these resources is not sufficient to satisfy the demand, production is directly affected by resource scarcity. In particular, we assume that, under supply-side constraints, consumption and investment demand might decline. Moreover, although all these resources are necessary for the production of goods based on our Leontief-type production function (i.e. there is imperfect substitutability), their relative use changes because of technological progress.

The way that carbon emissions affect climate change follows closely Nordhaus and Sztorc (2013). In particular, CO_2 emissions lead to an increase in atmospheric CO_2 concentration. The evolution of CO_2 concentration is affected by the carbon cycle that captures the exchange of carbon between the atmosphere and the upper ocean/biosphere and between the upper ocean/biosphere and the lower ocean. The accumulation of atmospheric CO_2 and other greenhouse gases increases radiative forcing. This increase places upward pressures on atmospheric temperature.

A crucial distinction is made between green capital and conventional capital. Compared to conventional capital, green capital is characterised by lower energy intensity, lower material intensity and

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[2] This is a term used in material flow analysis (see e.g. Krausmann et al., 2015). In general, socio-economic stock also includes animal livestock and humans. However, these stocks (whose mass remains relatively stable over time) are not included in our analysis. As will be explained below, socio-economic stock is measured in Gigatonnes.