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The EIRIN Flow-of-funds Behavioural Model of Green Fiscal Policies and Green Sovereign Bonds

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ABSTRACT

Fiscal and monetary policies, as well as new financial instruments, could play a key role to meet the Paris Agreement. However, deep uncertainty characterizes their design and their potential effects on growth, financial and credit market stability, and inequality. We develop the EIRIN flow-of-funds behavioural model to simulate the introduction of green fiscal policies and green sovereign bonds, and we display their effects on firms' investments in the brown and green sector, on unemployment, on the credit and bonds market. EIRIN is Stock-Flow Consistent and is rooted on a balance sheet approach. It adopts a Leontief production function with no substitution of the production factors, i.e., Labour, Capital, and Raw Materials. Its sectors are endowed with adaptive behaviours and expectations, and interact with the others and the foreign sector through a set of markets. Simulations show that green public policies can promote green growth by influencing firms' expectations and the credit market. Green sovereign bonds represent a short-term win-win solution, while green fiscal measures have higher immediate distributive effects that induce negative feedbacks on the economy. These results are influenced by the conditions (fiscal, budgetary and public debt/GDP) in which both measures are implemented.

1. Introduction

Mature economies such as the European Union (EU) are still struggling to get out of the so-called "secular stagnation". At the same time, climate change was recently identified as an additional source of risk for financial markets and for the real economy (see for instance Carney, 2015; ESRB, 2016; Batten et al., 2016). Besides the well-known climate physical risks (Stocker et al., 2013), recently climate transition risks started to be investigated, in particular those related to carbon stranded assets, i.e., assets that are at risk of losing much of their value as a result of *unburnable* reserves of fossil fuels (McGlade and Ekins, 2015). The realization of carbon stranded assets is expected to increase price volatility of both carbon-intense and renewable energy assets, affecting negatively the former and positively the latter (Fischer, 2015; Lazarus and Tempest, 2014). The reason is that the introduction of market-based solutions to climate change (such as a global carbon tax) aimed at decarbonizing the economy could directly and immediately affect the revenues and thus the assets' value of companies in carbon-intense sectors, and as a consequence the value of the portfolios of investors exposed to them.

Risk transmission from climate change to the financial sector started to be analysed and appears to be substantial (Dietz et al., 2016), with potential systemic ramifications and cascade effects throughout the entire financial network (Battiston et al., 2017). However, capital is flowing in the low-carbon economy at a much slower pace than needed to meet the 2°C target (Volz, 2017). While current investments in renewable energy reached USD 242 billion (bn) in 2016 (BNEF/UNEP, 2017), the International Energy Agency (IEA) has recently estimated that the retrofitting of the energy sector by 2035 would require investments worthy USD 53 trillion (trn).

Better disclosure of information on climate-related financial risk from the one hand (FSB TFCD, 2017), and the introduction of a stable green policy framework from the other hand (Stern, 2016) are recommended to provide investors the right signals and incentives to invest in a sustainable, inclusive and innovation-based growth. In this context, the role of green policies such as green fiscal and green monetary policies (see for instance Monnin and Barkawi, 2015; Mazzucato and Penna, 2015; Campiglio, 2016), and the introduction of new financial instruments, such as green sovereign bonds, gained attention among academics and practitioners. The political feasibility and

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the effectiveness of green public policies started to be addressed as well (Rozenberg et al., 2013; Rozenberg et al., 2017; Nemet et al., 2017). However, there is high uncertainty about their design, due to the lack of consolidated knowledge on their direct and indirect effects on the real economy and on financial markets. Moreover, their distributive effects and trade-offs, in terms of income inequality and wealth concentration across economic sectors and social groups, has not been properly addressed yet. Modelling methods based on general or partial equilibrium approaches, such as the Integrated Assessment Models (IAMs), are not able, by construction, to represent a complex system where the presence of cross-sector feedback loops and time delays at the macro-economic level, and heterogeneous short-term thinking agents at the micro-economic level, determines non-linearity and policy uncertainty (Mercure et al., 2016; Balint et al., 2017; Ackerman et al., 2009; Ackerman and Munitz, 2016; Scrieciu et al., 2013). Most important, IAMs don't include a credit and financial sector and omit modern money theory and banks' endogenous money creation (Wray, 2015; McLeay et al., 2014). This means that they are not able to display neither the dynamics of private debt (including the implications on risk creation and diffusion from the credit market to the real economy), nor the role of Central Banks on investors' expectations. Therefore, scholars started to recognize the need for bottom-up and out-of-equilibrium models rooted on complex system science to understand sources of systemic risk emerging from the interaction between climate change, the real economy, the credit and financial markets (Farmer et al., 2015; Battiston et al., 2016b). In particular, Rezai and Stagl (2016) called for the development of a new generation of models in ecological macro-economics able to integrate the micro-foundations of the models with a *meso* and macroeconomic level of analysis to better understand the feedback loops between the ecosystem, the real economy and the financial sector.

With the aim to contribute to this stream of research, we introduce EIRIN, which is a Stock-Flow Consistent (SFC) model rooted on a neo-Schumpeterian, evolutionary economics approach. EIRIN features heterogeneous economic sectors and subsectors characterized by adaptive behaviours and expectations (households, firms), heterogeneous capital goods characterized by different resource intensity, a credit sector characterized by endogenous money creation, and a foreign sector. In addition, EIRIN connects these elements with policy agents, such as a government that decides on the fiscal policy and issues green financial products (i.e., green sovereign bonds), and a Central Bank in charge of setting the monetary policy. EIRIN includes some novel elements to the expanding field of the ecological macroeconomics and environmental economics literature (see Dafermos et al., 2017; Lamperti et al., 2015; Ponta et al., 2016; Bovari et al., 2017). First, it endogenizes green technology investments and displays their effects on the changes in green technology adoption and thus on the level of resource efficiency of the production process, on the structure of the real economy, on credit market performance and on income distribution. This solution is alternative to the conventional environmental economic models that adopt a cost-benefit approach through market-based pricing (Stern, 2006; Weitzman, 2009), and are well-known for underestimating the negative externalities of climate change, as displayed by the social cost of carbon, and the distributive effects (see Ackerman and Stanton, 2012; Pindyck, 2013).

Second, it analyses the effects of resource intensive production and consumption on the performance of the real economy (e.g., employment, capital accumulation), of the balance of payments and credit market.

Third, it simulates two different sets of green public policies – i.e. green sovereign bonds *vis a vis* green fiscal measures – through which the government covers the cost of the introduction of green subsidies. Green sovereign bonds are issued by the government and subsidize firms' green investments, thus they have a clear conditionality associated with their use. Green public policies influence firms' green/brown investment choices, macro-economic performance and credit conditions. In addition, the Central Bank influences investment and consumption's decisions of the economic agents by setting the nominal interest rate. These modelling solutions are important when we want to understand the channels of transmission of different sets of green public policies on the sectors and subsectors of the economy.

The name EIRIN, which in ancient Greek means “harmony, peace”, was chosen because we believe that the goals of economic development and sustainability are not mutually exclusive but could be instead mutually reinforcing under specific policy conditions.

2. Methodology

2.1. Model Outline

EIRIN is a demand-driven model in the (post-) Keynesian tradition. EIRIN is SFC (Godley and Lavoie, 2007; Lavoie, 2014; Caverzasi and Godin, 2013; Caiani et al., 2015), and adopts a double-entry balance sheet accounting approach (Raberto et al., 2012; Bezemer, 2012) that contributes to increase the transparency and the consistency of results by tracking all the transactions within the economy, by recording all the changes in the stocks of assets and liabilities for each economic sector, and by displaying their relation with the changes in the flows across sectors. In so doing, we assure the correspondence between assets and liabilities, whose difference equals to zero. EIRIN can be described as a flow-of-funds model in so far it captures all the financial transactions and financial positions of all the sectors in the economy[1] in terms of production, consumption, employment, income inequality, the credit and the bonds market.

The EIRIN economy is shaped on a middle-high income country (such as the member states of the European Union, or the United States), which relies on fossil fuels and raw materials for its production and consumption processes. EIRIN is characterized by deterministic dynamics, and by a structure based on stocks interconnected through flows, where the stocks represent the balance sheet entries of the sectors (or representative agents), and the flows represent their cash and material in-and-out flows. EIRIN's elementary units and building blocks are the heterogeneous sectors of the economy, which could be considered as representative agents characterized by own adaptive behaviours and expectations. Indeed, in addition to stocks-and-flows' balance sheet relations, and to a dynamics based on the stocks' rates of change, EIRIN's sectors display an adaptive decision making and are endowed with own behavioural rules. Therefore, EIRIN's sectors' specific behavioural characteristics make them closer to the agents of an Agent-based model (ABM) than to the sectors of a System Dynamics model (SD), which displays aggregate sector behaviour. In this way, the model can support the representation of endogenous decision-making, which is fundamental to understand the drivers of sectors' intertemporal behaviours and their consequences on the dynamics of the system. This is the case, for instance, of investment decisions made by the consumption goods producers (i.e., the Net Present Value (NPV) of brown versus green investment decisions), who compare the short-term costs of investments with the discounted value of future expected cash flows.

EIRIN is populated by the following sectors: a household sector, which is divided into a worker and a capitalist agent; a banking sector, which is represented by a commercial bank; a Central Bank; a consumption goods production sector, represented by a firm (CGP); a capital goods production (KGP) sector, which is divided into two agents (KGP brown and KGP green); a government; a foreign sector, which provides the raw materials imported in the economy. The sectors interact through the following set of markets: consumption goods, capital

[1] The term flow-of-funds is widely used in post-Keynesian literature (see Tymoigne, 2006) in the context of macro-economic models based on systems of interrelated balance sheets, as well as by major Central Banks in the world. See for instance the US Federal Reserve, https://www.federalreserve.gov/releases/Z1/Current/ and the European Central Bank, Bê Duc and Le Breton, 2009.