Financial stability at risk due to investing rapidly in renewable energy

Karolina Safarzyńska\textsuperscript{a,*}, Jeroen C.J.M. van den Bergh\textsuperscript{b,c,d}

\textsuperscript{a} Faculty of Economic Sciences, Warsaw University, Długa 44/50, 00-241 Warsaw, Poland
\textsuperscript{b} ICREA, Barcelona, Spain
\textsuperscript{c} Institute of Environmental Science and Technology, Universitat Autònoma de Barcelona, Edifici Z - Campus UAB, 08193 Bellaterra, Spain
\textsuperscript{d} Faculty of Economic and Business Administration & Institute for Environmental Studies, VU University Amsterdam, The Netherlands

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\textbf{A B S T R A C T}

We present novel insights about effective energy policies using an agent-based model. The model describes relevant feedback mechanisms between technological evolution, the interbank market and the electricity sector. Analysis with it shows that energy policies affect interbank connectivity and hence the likelihood of cascades of bank failures. This effect has not been studied before in the literature. In particular, we find that investments in renewable energy reduce interbank connectivity, increasing the probability of bank failures, while raising taxes on energy has an opposite effect. Increasing the share of renewable energy in electricity production initially increases the price of electricity, and thus improves profits and the ability to re-pay debts of incumbent power plants. However, when the share of renewable energy increases too quickly, financial stability may be at stake as the burden of financing investments in renewable energy offsets the improved profitability of existing power stations. All in all, this study provides a unique and novel perspective on the relationship between renewable energy investments and financial stability.

1. Introduction

Policymakers concerned with sustainability transitions need models capturing feedback mechanisms between different sub-systems of the economy, so that they can simultaneously assess economic, social and environmental performance of anticipated public policies and strategies. But current studies tend to examine climate change, financial instability or inequality without considering their complicated interrelationships. As a result, they are incapable of identifying indirect effects of sustainability policies in social, financial and economic realms. Hence they may overestimate the effectiveness of various policies, particularly by overlooking potential effects of policies directed at one sub-systems on other sub-systems. The proposed new approach avoids this deficiency by accounting for interactions between financial, energy and social sub-systems. In particular, in this paper, we employ an agent-based model, capturing interactions between these interrelated systems.

The paper contributes to the literature on transitions to a low carbon economy, by assessing macro-economic impacts of associated policies. Most other studies adopt a more limited perspective, and as a result provide partial insights (Safarzynska et al., 2012). In order to understand the full implications of a transition, it is essential to adopt a macro-economic perspective as we propose in the paper. A low-carbon transition requires changes that will have non-trivial impacts not only on energy systems but also on financial systems and even income distribution. Recent evidence shows that both inequality and energy prices affect financial stability (Russo et al., 2013; Cardaci and Saraceno, 2015; ESRB, 2016). This illustrates that the three sub-systems are intricately connected. Yet, so far, they have been studied separately. With our model we aimed to fill in this gap, and try to assess important secondary effects of a range of transition policies.

It is increasingly argued that to guide a transition to a low-carbon world, new models are needed that integrate knowledge of social processes with that of technical aspects of climate and energy systems (Nature Energy, 2016; Stern, 2016). Integrated assessment models are widely used tools in studies of macroeconomic impacts of climate policies. These models rely on very simplified assumptions of consumers’ and producers’ behavior, and ignore bounded rationality and social interactions. Agent-based modeling (ABM) offers realistic representations of socio-economic processes, which allows simulating the economy through interactions between large numbers of distinct agents. Over the last two decades, macro ABMs have been successfully applied to study financial contagion (Cincotti et al., 2010; Gaffeo et al., 2008; Delli Gatti et al., 2009; Neveu, 2013), technological evolution (Windrum and Birchenhall, 1998, 2005), and the relation between inequality, structural change and financial fragility (Russo et al., 2013; Cardaci and Saraceno, 2015). So far, very few macro ABMs include...
energy as an input of production (exceptions are Gerst et al. (2013) and Wolf et al. (2013)), while no model combines energy and financial systems.

In the light of this, we modify an agent-based model developed by Safarzynska and van den Bergh (2017) to study macroeconomic impacts of policies aimed at guiding the economy along sustainable trajectories. The model conceptualizes relevant feedback mechanisms between technological evolution, labor and interbank markets, and the electricity sector. In the model, four populations, namely of heterogeneous consumers, producers, power plants and banks, interact through interconnected networks. The modeling of sustainability policies requires several changes in the earlier model. In particular, we modify the model to explicitly account for: subsidies and investments in different energy mixes in electricity production; energy efficiency measures; energy taxation, whose revenues are used to reduce the tax burden on labor; and redistributive policies. We show that sustainability policies affect the relationship between the interbank connectivity and the probability of bank failures, which has not been considered so far in the literature. For instance, policies increasing the share of renewable energy in electricity production reduce the interbank connectivity, increasing the probability of bank failures; while raising energy taxes acts in the opposite way. So far, no study has examined this effect either empirically or theoretically.

A main insight of our study is that a too quick transition to renewable energy can pose a serious burden on the financial system. Investments in renewable energy increase the price of electricity, and hence profits and ability to re-pay debts of incumbent power plants. However, if the share of renewable increases too quickly, financial stability may be at stake as the burden of financing investments in expensive renewable power plants offsets the improved profitability of gas power stations. This is because the costs of constructing a renewable power plant per MW installed capacity is still considerably higher than that of a fossil-fuel power plant. The detrimental effect of investments on the financial sector is especially pronounced in coal-dependent economies because investments required to set-up a coal power plants are larger than of CCGT. We will see that a solution is to combine renewable energy with combined cycle gas turbines (CCGT) in electricity production. This can improve the stability of the financial system.

The reminder of this paper is organized as follows. In Section 2, we describe the basic setup of the model and present a set of policy scenarios. Section 3 reports simulation results and interpretations. Section 4 concludes.

2. Model description

In this section, we describe the basic assumptions of, and modifications to, the model of Safarzynska and van den Bergh (2017). Fig. 1 presents a schematic structure of the model that highlights its modules and the described interactions between energy, labor and financial subsystems. We consider a product market with many firms producing highly differentiated goods. A technological trajectory arises from the interplay between incremental innovation and the search for new product designs by individual firms. This approach follows the seminal work by Nelson and Winter (1982). Evolving consumer preferences determine the direction of firms’ innovative activities, giving rise to demand-supply coevolution.

On the supply side, firms decide about a desirable level of production and associated use of inputs (labor, capital and electricity). Product quality changes over time as a result of learning-by-doing (experience). The effect of incremental improvements in product design on sales is uncertain. As a result of a change in product quality a firm can attract new consumers, while it may lose others. In addition, every period a new firm offering a new product design tries to enter the market. It asks a randomly chosen bank for a start-up loan. Similarly, incumbent firms can ask banks for loans, for instance, to invest in capital expansion. The loans are granted, and new firms can enter the market, if both conditions are satisfied: (1) a bank has sufficient liquidity or is capable of raising finance in the interbank lending market and (2) the debt-to-equity ratio of a firm asking for a loan does not exceed some critical value.

In the model, electricity is assumed to be an important input to the production of consumer goods, along with capital and labor. This is illustrated by electricity being essential to manufacturing: it can reach up to 95% of total energy use for production (Steinbuck, 2010). The electricity market is modeled as composed of energy companies with heterogeneous plants producing electricity from diverse energy sources, namely combined cycle gas turbines (CCGT), coal and nuclear energy. We model energy transitions as occurring through the installation of new power plants and the exit of obsolete plants. A plant is closed after reaching its maximum lifespan, and a new plant enters the market. The size of a new power plant and the type of energy technology it employs are chosen based on the discounted value of future investments. In addition, each new plant receives a loan, which has to be re-paid by the end of its lifecycle. Credit connections between banks and firms, including power plants, develop as a result of activities in the real economy. The basic model of Safarzynska and van den Bergh (2017) distinguishes between three abstract fuels. For the current analysis, parameters describing each energy technology are calibrated using data for the electricity industry in the UK between 1990 and 2002, following an earlier study (Safarzynska and van den Bergh, 2010a, 2010b). This period is relevant as it constituted a major transition of the British electricity sector from coal to gas. Installation costs and parameters describing changes in fuel prices were re-scaled by a factor 1/10 to match demand for electricity in the market for consumer products.

On the demand side, consumers imitate choices of others within their social networks. We distinguish three consumer classes based on the source of their income, namely owners of the factors capital and energy, and workers. This allows us to study the impact of distributive policies on financial and economic stability. Energy owners can be though of as shareholders of energy utilities or oil and gas companies, while capital owners may be regarded as small producers who own productive machinery. In the model, consumers evaluate the attractiveness of a product based on its quality, price and whether others in their socio-economic class have already adopted it. The stronger brand loyalty of the more likely consumer choices cluster around similar products. In addition, energy and capital owners derive disutility from buying products that are frequently bought by workers, which we refer to as a snob effect. Consumer differentiation is one factor behind income inequality, while the degree to which consumers imitate others in their social networks determines the extent of market competition.

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