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Analysis

Investing in a Green Transition☆

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ABSTRACT

At the Rio + 20 conference the world's governments affirmed a need to transition toward green economies, and background reports in preparation for the event emphasized the role of investment. Subsequent authors noted that private investment flows overwhelm public ones, arguing that private investment must be mobilized for a transition. However, the role of private investment in a major economic transition is poorly understood, particularly when the investment is not inherently attractive to investors and must be made attractive through policy. We present a model representing investment-macroeconomic interactions with classical features. Among its novel features is a distinction between "affected" sectors, which are sensitive to the amount of green capital in the economy because of network effects and forward-backward linkages, and "unaffected" sectors, which are relatively insensitive. We argue that affected sectors are both harder to change and nearer to the base of the economy. In model runs, we observe that in a green transition, the affected sector lags the unaffected sector with possible implications for a transition strategy. Thus, in the model, firm and investor behavior postpones deeper and more systemic changes until late in the transition.

1. Introduction

There is much recent discussion of the need to create a green economy and of what one might look like. The term "green economy" appeared in the title of a book by Pearce et al. (1989), which argued that conventional development was degrading natural capital and threatening long-term prosperity. In a report entitled "Towards a Green Economy" prepared for the 2012 United Nations Conference on Sustainable Development (Rio + 20), the United Nations Environment Program (UNEP, 2011) observed that a sequence of development disappointments and economic crises have fostered disillusionment with prevailing economic ideas. They further claimed that the crises and slow development progress came from a "gross misallocation of capital". The Organisation for Economic Co-operation and Development (OECD, 2011) prepared its own report for Rio + 20, "Towards Green Growth", which argued a need for investment and innovation to support continued growth that ensured the continuation of environmental services. At the Rio + 20 conference itself, the global financial crisis was sufficiently fresh in the minds of attendees for them to talk about alternatives. Although countries did not undertake specific commitments at Rio + 20 (Barbier, 2012), UN member states did so following the conference, with the adoption of the United Nations Agenda 2030 (UN General Assembly, 2015), including target 8.4, which calls on countries to "endeavour to decouple economic growth from environmental degradation", target 9.4, to "upgrade infrastructure and retrofit industries to make them sustainable, with increased resource-use efficiency and greater adoption of clean and environmentally sound technologies and industrial processes", and target 12.2, to "achieve the sustainable management and efficient use of natural resources".

Both the UNEP and OECD reports pointed to investment as a crucial area of concern. However, although UNEP did commission a simulation model, green investment flows were specified exogenously as a percent of GDP (UNEP 2011, 512), leaving open how those flows would be generated, how much would be public, and how much private. Noting the vastly larger flows available in the private sector, much discussion has focused on how private funds could be mobilized (Sullivan, 2011; Green Growth Action Alliance, 2013; IFC, 2013; Hongo and Anbumozhi, 2015). Proposed mechanisms focus on mitigating risks and enhancing rewards to attract investment. Yet, some of the risks are the consequence of collective outcomes at the level of the macroeconomy, and are out of the direct control of specific actors. In this paper we propose a stylized macroeconomic model as a contribution to understanding how to motivate green investment, with a particular focus on lock-in.

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The model in this paper is classical in its general orientation, in that sector prices are derived from a common target rate of return, wages are determined through a conventional wage share, and we smooth over business cycles. Medium and long-run outcomes are determined with Sraffian production prices (see, *e.g.*, Abraham-Frois and Berrebi, 1997). The economy grows at a steady rate in the model, but growth becomes unbalanced during the transition. Firms invest in fixed capital to meet anticipated demand, and they have a choice between "green" or "brown" investment. They finance their investment through retained profits, bank loans, and equity, with different markets for green and brown issues. In some "unaffected" sectors, productivity depends only on the choice of technology. In other "affected" sectors, network effects and dependence on backward and forward linkages mean that green capital performs best in a green-capital dominated economy, while brown capital performs best in a brown-capital dominated economy (Kemp-Benedict, 2014). Combined with inertia from incumbent firms, these interdependencies lead to lock-in in the affected sectors. Financial investors perceive green and brown investments as more or less risky, which influences how they allocate their wealth, while high market valuations can influence real investment.

The model has some novel features, particularly the distinction between affected and unaffected sectors, the representation of investors' perception of risk, and the application of a new asset allocation model (described in Kemp-Benedict and Godin, 2017). It is unusual in that it applies a balanced growth framework to focus attention on lock-in. The transition is characterized by deviations from balanced growth, a theme of classical development theory (Hirschman, 1958).

2. The Macroeconomics of Green Investment

This paper is a contribution to a broader research program on ecological macroeconomics (Harris, 2008; Rezai et al., 2013; Rezai and Stagl, 2016). Within that broader program, it applies a "green-brown capital" model to study the role of finance for a transition to a green economy.

2.1. Green-Brown Capital Models

Having entered the political arena, "green economy" has taken on a variety of meanings (Leach, 2015). For this paper we view it in the abstract as an economy dominated by "green" production systems, where such systems place sustainable pressures on the environment, without specifying either the systems or the pressures in detail. The model presented in this paper distinguishes green technologies, or production systems, from conventional "brown" technologies.

Green-brown capital models have been explored as a Ramsey problem by Van Der Ploeg and Withagen (1991), Rozenberg et al. (2013), Ackerman et al. (2013), and Nordhaus (2010), although not all of the papers use the terms "green" and "brown" to describe different types of investments. In these papers investment follows an optimal future path given knowledge of the probability of all future states of the world. Formulating economic processes as a Ramsey problem is questionable in the best of times, and difficult to maintain for a major socio-technological transition. In this paper we assume that firms face fundamental uncertainty as a matter of course, due both to processes outside of the economic system *per se* and to the unforeseen consequences of their and other firms' actions (Shackle, 1949; Emery and Trist, 1965; Davidson, 1982). Green-brown capital models that feature non-optimizing behavior include the stock-flow-fund models of Dafermos et al. (2017) and Monasterolo and Raberto (2018).

2.2. Investment for a Green Transition

Both Dafermos et al. (2017) and Monasterolo and Raberto (2018) are concerned with the role of financial processes and policy instruments in a green transition. They employ a stock-flow consistent framework (Godley and Lavoie, 2007), keeping explicit track of bank loans and, for Monasterolo and Raberto, equity shares. Dafermos et al. studied the role of firm leverage, noting that higher leverage reinforces the economic damage of environmental change. Expanding green credit, particularly when restricting conventional credit, reduced both financial fragility and environmental pressure. Monasterolo and Raberto studied the case of a resource importer, and found that green sovereign bonds both reduce imports and foster a green transition.

A number of other papers have also examined low-carbon investment from a macroeconomic perspective. Applying an optimizing framework, Barnea et al. (2005) studied the implications for the total volume of investment of making socially responsible investment (SRI) the norm. Rozenberg et al. (2013, 2014) discussed ways to influence brown and green investment through capital instruments, such as penalizing brown investment, as a way to overcome inertia in the incumbent technology. Campiglio (2016) pointed out that internalizing climate externalities through a carbon price is necessary, but not sufficient, to promote a low-carbon transition given the need for financing. Given the long aftermath of the 2008 financial crisis, Campiglio suggested that green macroprudential policies could both stimulate investment and direct funds in a green direction. Battiston et al. (2017) showed that the financial system is vulnerable to systemic crisis due to loss of value from stranded assets in climate policy-relevant sectors. Balint et al. (2017) reviewed agent-based models of green innovation, noting that they have made strides in representing the development and diffusion of new technologies, but have further work to do on representing firm decision-making and capturing interactions between related technologies. Balint et al. also briefly reviewed systems dynamics models of economy-environment interactions, noting that despite the potential they offer for feedbacks and complex behavior, they often make assumptions close to those of conventional CGE models.

2.3. Features of the Present Model

The model presented in this paper shares some features with the works surveyed above on investment for a green transition. It is a non-optimizing green-brown capital model, implemented as a systems dynamics model. It is given an explicitly stock-flow consistent structure, in which firms finance investment from retained earnings, bank loans, and equity emission, but after introducing the stock-flow consistent framework, we do not specify the distribution between internal and external equity, allowing us to abstract from the details of the transactions flow matrix when specifying the behavioral assumptions of the model.

Unlike other existing models, the one presented in this paper has classical features. In a purely green- or brown-capital economy, the economy settles onto a balanced growth path. On that path, GDP and investment grow at the same steady rate, savings are a constant fraction of output, and firms achieve a common target rate of return on their investments. In the transition, the economy continues to grow at the exogenously set rate, but growth becomes unbalanced. Investment in different sectors and technologies departs from the GDP growth rate, firms cannot obtain their target rate of return on all investments, and consumption is constrained to meet the savings needed to finance investment. That is, consumption is the buffer variable in household expenditure. This "forced saving" behavior (Taylor, 2004, 51) emerges in the model from the combination of steady output growth and fluctuating investment demand.

These simplifications allow for a clear focus on some aspects of technological lock-in. As with Rozenberg et al. (2013, 2014), we implement inertia through incumbency, but we also allow for systemic causes. We bring a concern from development theory – coordinated construction of forward and backward linkages in the transition to an industrialized economy – to the challenge of transforming established industrialized economies. Following Hirschman (1958), we ask how a sector locked in by existing networks can be transformed by stimulating the creation of new networks through downstream demand.