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Evolutionary models of sustainable economic change in Brazil: No-till agriculture, reduced deforestation and ethanol biofuels

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ABSTRACT

This paper examines the historical drivers and barriers of three mitigation actions in Brazil: the expansion of no-till agriculture, reduction of deforestation, and increased displacement of gasoline with ethanol. The characteristics of these three economic changes align with evolutionary economic theories rather than neoclassical or environmental economics. Despite its cost-effectiveness, diffusion of no-till agriculture was contingent on social learning and flows of information within the agricultural regime. Brazil's success in reducing deforestation rates was driven not by policies that changed the microeconomic calculation of farmers, but by command-and-control policies on deforestation enabled through landscape shifts. Brazil's ethanol biofuels industry emerged due to both niche level innovation of ethanol production systems and pure-ethanol vehicles, and shifts at the landscape level that enabled mandated fuel blends, public procurement programmes, and public investment in R&D. These three economic changes correspond with the categories of reproduction, transformation and transition, respectively.

1. Introduction

Between 2005 and 2009, Brazil's annual greenhouse gas (GHG) emissions fell by 25%. This level of reduction is usually reserved for economies undergoing recession or collapse. However, over the same time period, Brazil achieved an economic growth rate of 3.5% per year (Viola, 2013). The primary cause of the reduction was a rapid decline in deforestation rates in the Amazon.

In 2009, with a successful record in hand, the Government of Brazil (GoB) set precedence among non-Annex 1 countries by incorporating a GHG emission reduction target into national law. Brazil's Federal Law No. 12,187 declared a relatively ambitious GHG emission reduction target of 36.1-38.9% against a business-as-usual trajectory by 2020 with a baseline year of 2005. The GoB subsequently submitted this target, along with eleven Nationally Appropriate Mitigation Actions (NAMAs), to the United Nations Framework Convention on Climate Change (UNFCCC) (La Rovere et al., 2014). More recently, Brazil's became the first developing country to pledge absolute emission reduction targets. Brazil's 2015 Intended Nationally Determined Contribution to the UNFCCC stated its aim to reduce GHG emissions by 37% against 2005 levels by 2025, and 43% against the 2005 levels by 2030.

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This paper will focus on three of the mitigation actions that the GoB aims to employ to achieve its targets: the expansion of no-till agriculture, the reduction of deforestation in the Amazon, and the increased displacement of gasoline with ethanol. The mitigation actions were chosen because each of them is situated in a historical context spanning decades, and therefore offers an illuminating case through which to study economic change towards low-carbon economies. The goal of the paper is to identify the different factors that drove and inhibited each mitigation action over the previous four decades to inform theories of economic change.

Much of the investigation into the mechanics of economic change to low-carbon economies, and how such change can be induced and managed, has been driven by neoclassical economics and environmental economics. In these streams of microeconomic inquiry, low-carbon technologies and practices will diffuse seamlessly through market forces when and where they offer greater economic benefits and lower costs than their alternatives.

Evolutionary theories of economic change offer an alternative to neoclassical and environmental economics. Evolutionary perspectives observe that a holistic understanding of the forces that drive and inhibit economic change requires a broader perspective that incorporates non-price-based factors such as innovation, knowledge flows, institutions, and politics at all scales. Ultimately, this paper finds that Brazil's experiences of no-till agriculture, reduced Amazon deforestation and ethanol biofuels aligns more closely with evolutionary economic theory than neoclassical or environmental economics. Specifically, these cases correspond with three different categories of economic change identified by Geels and Kemp (2006): reproduction, transformation and transition.

The following section discusses the different economic theories in depth. Section 3 provides the literature reviewed and methodology used to determine the GHG emission implications, costs and benefits, and historical drivers and barriers of no-till agriculture, reduced Amazon deforestation and ethanol biofuels in Brazil. Section 4 examines the three mitigation actions independently. For each action, the implications for GHG emissions are considered, followed by a microeconomic analysis and an in-depth historical analysis of factors that drove and inhibited economic change over the previous four decades. Section 5 concludes with a discussion on the lessons that can be drawn for both economic theory and policy.

2. Alternative theories of economic change

2.1. Neoclassical and environmental economics

Neoclassical economics hinges on economic equilibrium models where prices of a product or service, and the quantity produced, are determined by the forces of supply and demand. In these models, rational economic agents – acting according to price-based market signals to maximise returns – drive economic change in a linear manner towards an equilibrium state in which supply matches demand. Each one of these elements – prices, outputs, supply, and demand – can be altered by tinkering with another in the system.

Environmental economics applies equilibrium modelling techniques to study human's interaction with environmental resources. It views the primary cause of climate change to be market failure. More specifically, it views greenhouse gas emissions as an *externality*. Private actors that invest in emission-intensive activities are able to offload, or *externalise*, the negative costs onto society (Stern, 2007).

The textbook solution to address this market failure is for governments to align private and social costs and benefits through measures that add an extra price to activities that produce GHG emissions, such as cap-and-trade systems and carbon taxes. With a carbon price, households and firms will be incentivised to reduce emission-intensive activities, and low-carbon technologies and practices will diffuse seamlessly through market forces as they become more competitive.

From an environmental economics perspective, the carbon price should be set equal to the marginal externalised damage caused by GHG emissions, i.e. the social cost of carbon. At this level, barring further market failures, market forces will drive economic change to a new equilibrium state with an optimal level of GHG emissions, i.e. a state with the lowest net cost to society from climate change and climate change policies (Stern, 2007).

2.2. Evolutionary theories of economic change

From an evolutionary perspective, one of the foremost contradictions in equilibrium models is their treatment of innovation as an exogenous factor. Once innovation is considered endogenous to an economic system, it is clear that assumptions of long-term equilibrium cannot hold. For this reason, Schumpeter (1942, pp. 81–82) argued, "Capitalism (. . .) is by nature a form or method of economic change and not only is but never can be stationary."

Nelson and Winter (1982) further questioned neoclassical economics models assumption of rational behaviour. They observed that rather than re-evaluating their actions to capture the greatest economic returns, firms and individuals tend to act according to *routines*. Routines were viewed as analogous to genes in evolutionary biology, because both play an important role in information transmission (Nelson and Winter, 1982). Heredity of routines can occur in a vertical manner, for example, as parents pass down information to their children. Unlike genes, heredity of routines can also occur in a horizontal manner, as individuals and organisations learn from one another through education systems, media, government extension programmes, inter-firm knowledge spill-overs, etc.

Nelson and Winter (1982) likened the process of innovation in economies to that of mutation in biological evolution in that both introduce novelty into the system. However, unlike mutation, innovation is often deliberate. Firms will aim to get