What are the economic and environmental effects for Brazil of lifestyle changes as a global emission mitigation strategy?

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ABSTRACT

Recent studies have highlighted the importance of both land-based and demand-side mitigation to help meet the Paris Agreement targets. This paper focuses on the emission abatement efforts from the demand perspective, particularly lifestyle changes in the form of sustainable or healthy diet. While some efforts have been made to incorporate lifestyle changes into future climate change scenarios, it remains an open question how originally global suppliers of emission-intensive products will respond to lifestyle-based mitigation strategy at global scale. If political measures are adopted to guide those consumption changes, Brazil could be largely affected. Besides its potential as an important global food supplier, producing and exporting agricultural commodities has driven Brazil's economic growth. Brazil could also play a key role in the production of bioenergy. The paper accounts for some of the challenges related to the use of land and energy, and models mitigation scenarios between 2025-2050 using a computable general equilibrium model, the EPPA6. Results indicate the existence of detrimental economic effects and exploit the beneficial implications of mitigating climate change via demand-side, creating space for feasible supply-side decarbonisation.

Keywords: climate change scenarios; demand-side mitigation; lifestyle changes; computable general equilibrium model; Brazil

JEL classification: D58; P46; Q10

1. Introduction

The Paris Agreement sets out a global framework in which countries should pursue efforts to reduce their greenhouse gas (GHG) emissions to levels that would prevent the global temperatures from increasing more than 2°C above

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pre-industrial levels, ideally at 1.5°C. As a global attempt to develop effective climate change mitigation strategies, those endeavours rely heavily on an ensemble of emissions pathways provided by the Intergovernmental Panel on Climate Change (IPCC). In its most recent report version (IPCC, 2019), land-based mitigation solutions emerge as one of the main promising way to achieve stringent climate stabilization targets. This prominent role of land ecosystems is due to their ability in delivering negative emissions, i.e., to remove CO_2 from the atmosphere thereby reducing the carbon debt.

Considering the increasing pressures to promote rapid emissions reductions, negative emissions technologies (NETs) turn out to be an important component of a long-term mitigation portfolio, particularly bioenergy with carbon capture and storage (BECCS) and afforestation/reforestation. However, potential negative trade-offs emerge from the large-scale deployment of land-based mitigation solutions, which include food security (food prices), water resources and biodiversity. There are also concerns and uncertainties on land degradation as well as the potential feasibility and costs of large-scale implementation, especially in the case of BECCS. Even though BECCS has the double capacity of contributing with the decarbonisation of the energy sector, it is not yet readily available, thereby facing constraints in terms of technology diffusion at the scale necessary to limit global warming well below 2°C by 2100.

From the debate revolving the use of purely technological solutions, there is growing consensus of their limited potential to fully deliver a transition towards a low-carbon society (Brown and Vergragt, 2016). This holds particularly if the current western consumption patterns are adopted in emerging middle-classes, reducing the chances of stabilizing emissions at safe levels. It seems unlikely, though, that addressing the climate change problem will not involve changes in lifestyles, that is, replacement of emissions-intensive consumption for a different (relatable) and more sustainable consumption (van den Berg *et al*., 2019). The influence of behaviour, lifestyle and culture on energy use and associated emissions has been recognised at the IPCC report (IPCC, 2019), which suggests that more sustainable consumption practices would serve as a complementary solution to ensure staying within the global environmental boundaries (Edenhofer *et al*., 2014).

The pattern of consumption is one of the key drivers of environmental change setting the scale of the global development challenges. The recent demographic and economic growth of middle-income countries has contributed to an unprecedented increase in global consumption and emissions. This trend is projected to grow steeply since global population is expected to increase (Girod *et al*., 2013). Three categories of consumption are particularly relevant for mitigation purposes, namely the type of diet, passenger transportation and residential energy use.

According to Prudhomme (2019), the main source of emission reduction in dietary change scenarios is the ruminant farming sector. Sustainable diets imply reducing beef consumption, partly substituting the protein consumption with legume protein consumption while prioritising seasonal and local products (Pernollet *et al*., 2017; Hedenus *et al*., 2014). Concerns over the climate impact of animal product consumption have fuelled the imposition of measures such as environmental impact labelling (Leach *et al*., 2016), dietary recommendations (Gonzalez Fischer and Garnett, 2016), and taxes (Springmann *et al*., 2016).

Behaviour shifts in passenger transportation can help decrease oil demand. Strategies include avoiding travel or the use of non-motorized transportation when possible, prioritizing public transportation over private vehicles, opting for biofuels instead of fossil fuels or replacing internal combustion vehicles by electric and hybrid ones. Another mitigation option from the consumption side is to decarbonise household energy demand. Given that per capita electricity consumption is expected to increase with income, in combination with smaller households and growing appliance ownership (Cabeza *et al*., 2018), especially the use of air conditioning (Daioglou *et al*., 2012), extending their lifetime or replacing the old items by more efficient is rather necessary.

Those consumption-based mitigation options have received little attention in the climate policy literature (Creutzig *et al*., 2016). The vast majority has focused on the main drivers of demand and carbon footprint, by delimiting the effect of one or more “green actions” at the household level whether by bottom-up approaches (Moran *et al.*, 2018; Wood et al., 2018; Wynes and Nicholas, 2017), or economy-wide effects from economic models (Dai *et al*; 2012; Shukla *et al*. 2008). Most importantly, at least to our knowledge, none of them have investigated how those lifestyle changes in global scale may fall on originally global suppliers of emission-intensive products, particularly those in lower stages of development.

Previous studies documenting the impacts of consumption-based mitigation have called for greater geographic specificity, as most have examined almost exclusively industrialised countries, or a regional and global aggregates (Aleksandrowicz *et al*., 2016). This paper aims at understanding the economic and environmental effects for Brazil of lifestyle changes as a global emission mitigation strategy. Brazil has the potential to be an important global food supplier in the context of growing demand for food. The performance in the production and export of agricultural commodities has required the expansion of the agricultural frontier, which has also driven Brazil's economic growth. A large share of the Brazilian exports is also led by mineral fuels, including oil.

In order to fulfil global consumption demand at the scale projected, further expansion would likely involve replacement of forests (Alexandratos and Bruinsma, 2012) and the exploitation of natural resources, thereby contributing with further deforestation, land degradation and emissions. Associated environmental effects are generally embedded in the international exports. In middle-income and export-oriented countries such as Brazil, the relevance of environmental issues to society is highly determined by economic growth, ergo by international pressure. If Brazil maintains a disrupted environmental agenda as the one current in place, it may face severe implications in terms of trade retaliations and competitiveness, ultimately negatively affecting the national development as well as the global climate. Hence, future low-emission global scenarios may pose a challenge for the Brazilian economy, despite the potential key role it may play in the production of bioenergy.

By accounting for those challenges, this paper contributes to filling a research gap where emission mitigation strategies are optimistically applied worldwide. Using a computable general equilibrium (CGE) model, a robust tool suitable for energy-economy-environment investigations, the simulations emphasise the demand side mitigation, which entails different levels of shifts in the consumption pattern for the 2025-2050 period. The reference case for the consumption changes is the Business as Usual (BAU) scenario. The alternative pathway considers the adoption of more environmentally friendly behaviour, in line with the 1.5°C and 2°C of global warming goals. Scenarios are distinguished between optimistic, moderate, and pessimistic. Modelling details are provided in Section 2, with description of both the model and scenarios. Section 3 presents and discusses the evidence of the demand-side mitigation effects for Brazil whereas Section 4 synthetizes the major conclusions, elucidating limitations and suggesting future developments of the analysis.

2. Methodology

For modelling lifestyle changes into the climate policy portfolio, we use the Economic Projection and Policy Analysis (EPPA) model in its most recent version - EPPA6[2] (Chen *et al*., 2015). This is a computable general equilibrium model (CGE) developed by the MIT Joint Program on the Science and Policy of Global Change. EPPA6 was developed as a nonlinear complementarity problem in the General Algebraic Modelling System (GAMS) programming language (Brooke *et al.*, 1998), using the syntax of the MPSGE (Mathematical Programming System for General Equilibrium) algorithm developed by Rutherford (1999).

This version is based on the social accounting matrixes from the Global Trade Analysis Project Version 8 (GTAP 8) database, with a benchmark year of 2007 (Narayanan *et al.*, 2012). The level of aggregation is presented in Table 1 and includes developed and developing regions. The data is aggregated into 18 regions, 14 sectors and 14 “backstop” technologies[3] for generating energy, including renewable technologies such as wind and solar generation. Additional data sources on energy use and energy consumption (IEA, 2012), CO_2 emissions[4] related to cement production (Boden *et al.*, 2010) and CO_2 emissions related to land use change (Riahi *et al.*, 2007) are also used.

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[2] Free public version is available at: https://globalchange.mit.edu/research/research-tools/human-system-model/download .

[3] These technologies consist of new or alternative energy technologies.

[4] Other non-CO_2 GHG emissions and urban pollutant emissions are accounted for in EPPA6 from the EDGAR database Version 4.2 ((European Commission, 2011), including: methane (CH4), perfluorocarbon (PFC), sulfur hexafluoride (SF6), and hydrofluorocarbon (HFC).

Table 1

Regions, sectors and backstop technologies in EPPA6

Regions	Sectors	"Backstop" Technologies
United States (USA)	*Agriculture*	First generation biofuels (bio-fg)
Canada (CAN)	Crops (CROP)	Second generation biofuels (bio-oil)
Mexico (MEX)	Livestock (LIVE)	Oil shale (synf-oil)
Japan (JPN)	Forestry (FORS)	Synthetic gas from coal (synf-gas)
Australia and New Zealand (ANZ)		Hydrogen (h2)
Europe (EUR)[5]	*Non - Agriculture*	Advanced nuclear (adv-nucl)
Eastern Europe (ROE)	Food production (FOOD)	IGCC w/ CCS (igcap)
Russia (RUS)	Services (SERV)	NGCC (ngcc)
East Asia (ASI)	Energy-intensive (EINT)[6]	NGCC w/ CCS (ngcap)
South Korea (KOR)	Other industry (OTHR)	Wind (wind)
Indonesia (IDZ)	Transport (TRAN)	Bio-electricity (bioelec)
China (CHN)	Ownership of Dwellings (DWE)	Wind power combined with bio-electricity (windbio)
India (IND)	*Energy supply*	Wind power combined with gas-fired power (windgas)
Brazil (BRA)	Coal (COAL)	Solar generation (solar)
Africa (AFR)	Crude oil (OIL)	
Middle East (MES)	Refined oil (ROIL)	
Latin America (LAM)	Gas (GAS)	
Rest of Asia (REA)	Electricity (ELEC)	

Source: Based on Chen *et al.* (2015).

The model considers a long run simulation horizon, being solved at 5 yearly intervals. EPPA6 enables projecting scenarios of world economic development and emissions trends. It also projects the economic impact of proposed mitigation and energy policies, welfare and equity measures. Although most of the up-to-date model-based scenarios that explore strategies for climate change mitigation are generated by Integrated Assessment Models (IAMs),

[5] The European Union (EU-27) plus Croatia, Norway, Switzerland, Iceland and Liechtenstein.
[6] Energy-intensive industries in EPPA6 consist of those producing paper products, chemicals, mineral products, ferrous metals, metal products and cement.

EPPA6 is an adequate tool to measure the economic and environmental effects of the policy assumptions regarding the set of lifestyles change scenarios framed in this paper. At this stage of the study, a comprehensive representation of lifestyles change is not a requirement to fulfil since it aims at understanding the adoption of a certain (sustainable) consumption behaviour and its influences on emissions-intensive suppliers.

As a multi-region and multi-sector CGE model, EPPA6 provides a detailed representation of production and consumption of various sectors in each region, with corresponding greenhouse gas emissions (GHG). It also includes explicit treatment of inter-industry interactions and keeps track of bilateral trade in all goods. EPPA6 is a dynamic recursive model, i.e., it is solved for a sequence of global market equilibrium considering "myopic" expectations of economic actors[7], that provides a representation of the global economy (Chen *et al.*, 2015), including Brazil.

There are production functions for all sectors describing the use of primary factors (capital, labour, and natural resources), energy and intermediate inputs for producing goods and services in each of these periods. The level of consumption is modelled through a representative agent[8] that seeks to maximise utility by choosing how to allocate its income with respect to the utilisation of goods and services (Gurgel and Paltsev, 2014). The level of production of each economic sector results from the choice among primary factors and intermediate inputs in order to maximise profits, given the available technology and market prices. Statically, all markets reach a simultaneous equilibrium when zero-profit, market-clearing and income balance conditions are satisfied. Dynamically, EPPA6 is exogenously specified[9] and endogenously determined.

[7] The assumption of myopic expectation in EPPA means that current period investment, savings, and consumption decisions are made on the basis of prices in each 5 year period (Paltsev *et al.*, 2007).

[8] EPPA6 accounts for three economic agents: consumers (households), producers and government.

[9] Referred to Chen *et al.* (2015), exogenous factors are GDP projections for BAU growth, labour endowment growth, factor-augmented productivity growth, autonomous energy efficiency improvement (AEEI), and natural resource assets.

2.1. Policy scenarios

There are several options for specifying climate mitigation policy in EPPA6. The model allows for representing emissions constraints and to impose a carbon price on specific productive sectors and regions, for instance. In this policy analysis, the assumption is that all regions are subject to emissions reduction targets, but three regions are exempted from taking measures to induce lifestyle changes of diet, notably AFR, LAM and REA. In consideration of the principles of equity and common but differentiated responsibilities, as set up at the Paris Agreement, these regions are treated differently in an effort to account for their historical emission levels as well as the vulnerability to climate impacts and economic capabilities. For the others, it is presumed the implementation of policies to help promote the shifts in consumption accordingly.

Both national and international demand are particularly relevant for the analysis, given the global aspect of the climate mitigation objective. With focus on the food domain of lifestyle change, the description of this driver of global environmental change is exogenously specified as to represent the hypothetical future scenario of low demand for emissions-intensive food. In this approach, the developed scenario is based on the idea of sustainable and healthy diets, which includes a reduction in the demand for meat, whether supplied by domestic or international markets, specifically via Brazilian exports.

Three scenarios are modelled for this purpose: i) optimistic, ii) moderate and iii) pessimistic. In addition to defining different levels of demand shifts, the population size is also incorporated in the scenario design. This is important for two reasons. Firstly, because more food is necessary to satisfy the demand of an increasing population. This growing demand for food implies large land requirements, and makes it challenging to conciliate the various use of land (for food production, growing forest or biomass production – alternative energy). Secondly, due to uncertainty with respect to the feasibility of demand-side mitigation, i.e., the capacity to condition the consumer preferences to products less emission-intensive based on sustainable and healthy purposes.

Brazil is also subject to these changes in consumption in the simulations. In view of the climate-orientation of the current government, the policy measures imposed on the Brazilian exports of food products intensive in emissions appears to be likely if such production continues coming at the cost of deforestation. The resulting implication of the scenarios modelled for Brazil are presented and discussed in the next section.

3. Evidence of the demand-side mitigation effects for Brazil

4. Conclusions

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