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An Analysis of the Effectiveness of Climate Policy Instruments for Biofuels and Low Carbon Agriculture in Brazil

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Abstract

The gaps between the desired reductions in Greenhouse Gas (GHG) emissions—those declared by signatories of the Paris Agreement—and the reductions actually obtained are the principal motivation behind this work. This study reviewed the recent literature on the topic in the form of narrative analysis, a non-systematic analysis. Additionally, it analyzed documents, laws, and regulations, and collected quantitative data on institutional websites. This study provides an overview of the combinations of different instruments adopted, thereby contributing to an understanding of the advancements and obstacles influencing their effectiveness. The biofuels program mandates their blending with fossil fuels at distribution companies, combined with tradable carbon certificates and instruments of financial, fiscal, and technological incentives; this has demonstrated effectiveness in meeting mitigation targets, with indications that such arrangements facilitate the accomplishment of sector mitigation potentials. Non-mandatory instruments in the low-carbon agriculture plan, with public funds to support cheap agricultural credit, have also met their overall targets. However, there is no evidence that such instruments can effectively pursue the sector's greatest mitigation and development potential: the restoration of degraded soil and pastures, the targets of which only one-third were accomplished in a decade. Following the biofuels program model, a mandate to gradually incorporate products with lower carbon emissions into the supply chains of meatpacking and dairy companies—key components of the livestock value chain—and also to leverage tradable carbon certificates, may not only enhance carbon reduction, but also promote economic and socio-environmental opportunities for small and medium-sized rural farmers.

Keywords

Policy instruments; Biofuels; Low carbon agriculture; Climate policy.

1. Introduction

With a clear upward trend in the global quantity of greenhouse gases (GHG) in the atmosphere (United Nations Environment Program, UNEP, 2020), a group of 38 scientists headed by Mark Roelfsema has concluded that achieving the reduction targets for global emissions, from the climate agreement signed in Paris in 2015, will not be possible if efforts do not stretch well beyond the political strategies adopted by the various countries until the present day. For Roelfsema et al. (2020), GHG emissions would now be 5.3% higher if national policies and programs had not been adopted by the seven major emitting countries covered in the study, including Brazil. However, the effectiveness of these policies leaves a disparity of 28 billion tons of CO_{2eq}, a quantity measurement that aggregates

carbon dioxide (CO_2) emissions with those of other greenhouse gases, which are equivalently capable to CO_2 of causing the phenomenon of global warming.

A surplus to be reduced that corresponds to ten times Brazilian annual emissions, or to five times U.S. annual emissions, highlighting the lack of effectiveness of the policies, policy instruments, and public and private strategies adopted to date. We have already far exceeded the boundaries of the atmospheric concentration of CO_2 and other gases considered safe by Richardson et al. (2023), determined at 350 ppm, when considering the concentration of 280 ppm from the pre-industrial period. The current concentration of 417 ppm (UNEP, 2020) is dangerously close to the high-risk threshold, determined at 450 ppm by the scientists, public agents and private actors who gathered to meet in Kyoto in 1997.

Originating from the shortfall between the desired reductions and those achieved, discussion has arisen about the effectiveness of climate policy instruments adopted by the various countries, in pursuit of the goals declared under the Paris Agreement. This discussion is far from a consensus among researchers working on the topic. Drews et al. (2024), when analyzing six types of climate policies effectiveness, in questionnaires completed by 789 scientific researchers from differing fields, found that direct regulation is considered by respondents to be the most effective policy for mitigating emissions, followed closely by support for innovation, carbon taxation and information mechanisms. Subsidies for the adoption of mitigation actions and cap-and-trade are considered less important, with carbon taxation being preferred over cap-and-trade, notably between researchers from the European bloc and those from the U.S., despite the success of the European Emissions Trading System. Economists are the least enthusiastic about direct regulation, and the most sympathetic to the idea of carbon taxes. Interestingly, sociologists are the most averse to information politics. Most economists overestimate carbon pricing, and most other scientists underestimate it. Among those who added their comments to the questionnaire, the majority highlighted the importance of considering the context of each country in any analysis.

Direct regulation, pricing or taxation of emissions, fiscal and tax mechanisms, incentives for the adoption of technologies, awareness and information, and efficiency in the generation and use of energy, among other instruments, are not utilized in isolation: they often form arrangements among themselves. Analyzing the effectiveness of these arrangements also appears to be on the frontier of scientific research about national and sectoral climate governance (IMF, 2023; Drews et al., 2024).

From this debate the following question emerges: which arrangements between different climate policy instruments, at different levels of application, have been effective in achieving GHG emissions reduction targets in Brazil? Based on a non-systematic review of the recent literature on this topic, in the form of narrative analysis, the objective of this study is to analyze the effectiveness of climate policy instruments in meeting the targets for reducing GHG emissions established in the National Biofuels Policy, the Renovabio program, and in the National Low Carbon Agriculture Plan, the ABC Plan.

2. Method

Siddaway et al. (2019), and Galvão and Ricarte (2020) recommend such a narrative analysis, a non-systematic review of the literature, to derive robust conclusions on major questions and principles, serving as an exploratory exercise in assessing the extent to which the existing literature supports a proposal or new ideas. Therefore, a literature review was conducted on articles published from 2015, the year in which the Paris Agreement was proposed, and onwards, on the Web of Science, Science Direct and Scopus databases, with the following search terms: Policy instruments; Climate governance; Biofuels; Low carbon agriculture; Climate policy; and Brazil. Additionally, national laws and regulations on the Brazilian Biofuels Policy (Renovabio) and the Low Carbon Agriculture Plan (ABC Plan) were analyzed. The legal framework and quantitative data of the two programs were also reviewed, found in the institutional databases of the National Agency of Petroleum, Natural Gas and Biofuels (ANP, 2022), the Ministry of Agriculture, Livestock and Food Supply (MAPA, 2023) and the Ministry of Mines and Energy (MME, 2023).

The effectiveness analysis of different arrangements between policies and climate policy instruments is undertaken by contrasting the instruments adopted in biofuels and low-carbon agriculture programs with their effectiveness in achieving reduction targets. Goals and deletions declared in the databases of public institutions that implement,

monitor and evaluate the programs are used. Ebadian et al. (2020) also seek to combine the literature review and secondary data obtained from official websites, when dealing with policy instruments and market mechanisms to promote biofuels. They have also indirectly sought the effectiveness of mandatory and voluntary instruments to promote the production and consumption of biofuels. This research undertakes a similar activity, only more directly, by seeking emission and suppression data from Brazilian federal government websites that regulate the biofuel and agriculture sectors, given the ease of interpreting legislative language and the accessibility of both emission and suppression inventory data in local databases. Using a similar methodological approach, combining a non-systematic literature review with data obtained directly from governmental or reputable non-governmental agencies, Silva et al. (2018), Costa Jr. et al. (2019), Arango et al. (2020), Carrer et al. (2020), Goes et al. (2020), and Wills et al. (2022) conducted their studies.

3. Results

Of the approximately 1200 climate laws enacted around the world, Eskander and Fankhauser (2020) demonstrate the significant participation of Brazil in the formation of this regulatory framework (Figure 1). This country is among those that have enacted the highest number of climate laws thus far. Up to March 2024, 27 laws, decrees, ordinances, norms or resolutions have been identified, enacted since 1994 in Brazil to regulate climate change. This includes any framework of laws or instruments that implies the adoption of programs and actions on both a mandatory and a voluntary basis, or even arrangements between the two categories and other instruments. Incentives for the adoption of technologies, awareness and information programs, efficiency in the generation and use of energy, pricing or taxation of emissions, and fiscal or tax mechanisms are some of these.

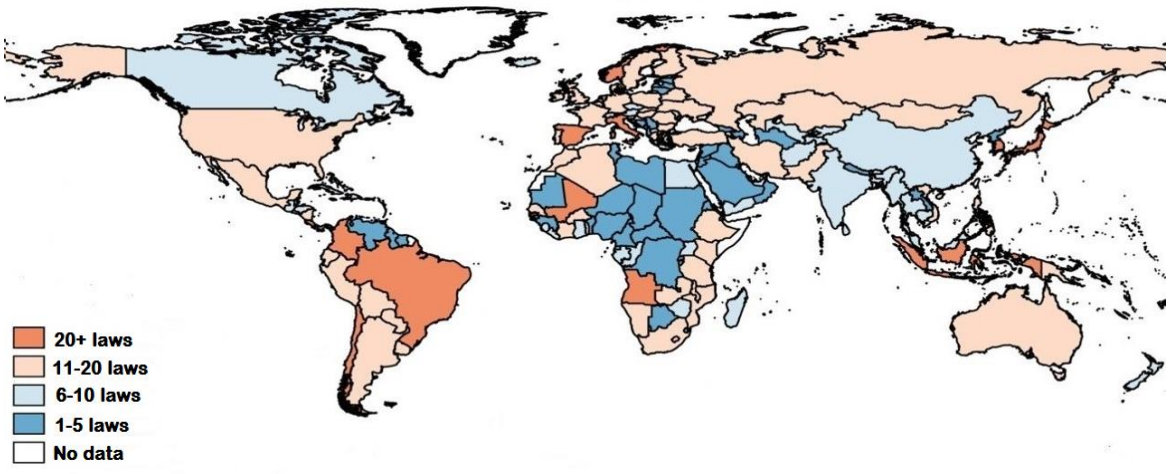

Figure 1 – Number of adopted laws related to climate change by country, Source: Eskander and Fankhauser (2020).

3.1 The Brazilian biofuels program

The National Biofuels Policy (Renovabio), established by the Law No. 13,576 of 2017, based on blending mandates, imposes the inclusion of biofuels within the national fossil fuel distribution chain. It involves technological innovation, attraction of investments, the independent ensuring of socio-environmental responsibility in the production chain, increases in productivity, and increases in energy generation through the use of biomasses. However, it is falling short of attaining its full potential, being capable of maturing further in order to safely achieve its objectives (Grangeia et al., 2022). Glyniadakis and Balestieri (2023), discussing scenarios for the electrification and technological distribution of light vehicles in Brazil, found that the contribution of the biofuels program must not be underestimated, under any analysis, to decarbonize the fleet of light vehicles within the country. They concluded that the most favorable scenario is the incorporation of electric vehicles, along with the increased use of ethanol in light internal combustion vehicles. This fuel is considered by the authors as being the most sustainable source, and the role of the biofuels program as the most critical. They deduce, however, that without going beyond Renovabio's current targets, the national targets of reducing emissions by 23% up to 2030 and by 58% up to 2050 are difficult to achieve, as the sector's emissions may grow by as much as 134%, between 2020 and 2050, even with ethanol consumption surpassing that of gasoline. Deductions are based on the tendency for the fleet of light combustion

vehicles to increase, even with the possible integration of 10% per year of electric vehicles, and the tendency for the average distance traveled by each light vehicle in circulation to increase, which may exceed around 12,000 km/year in 2020, to around 22,000 km/year in 2050.

However, there is no evidence that the goals of Renovabio cannot be expanded, as the current ones are being achieved, as highlighted in Table 1. The combination of a blending mandate, and a regulated instrument for the carbon market seems decisive for this effectiveness in the Brazilian context, an agriculturally capable country that has been investing in the production of biofuels since 1975, in response to the 1973 global oil crisis. Table 1 highlights the period from 2020 to 2025 and the years 2030 and 2033, with targets given in millions of Decarbonization Credits (CBIO). Each CBIO is equivalent to one ton of CO_2 avoided.

Table 1 – GHG emissions reduction targets between 2020 and 2025, in 2030 and in review until 2033, Sources: ANP, 2022 and MME, 2023.

	2020	**2021**	**2022**	**2023**	**2024**	**2025**	**2030**	**2033**
Target in millions of CBIO per year	**14.53**	**24.86**	34.17	42.35	50.81	58.91	90.67	-
Review of goals (CNPE, resolution No. 6 of 2023)				**37.47**	**38.78**	**42.56**	**64.08**	**90.67**
CBIO issued in millions per year	**18.50**	**30.88**	**31.23**					
Tolerance intervals: upper limit and lower limit	-	-	-	42.67	50.85	59.31	67.41	99.17
	-	-	-	25.67	33.85	42.31	50.41	82.17

The review by resolution number 6 of the National Energy Policy Council (CNPE), of 2023, postponed to 2033 the target of 90.67 million regulated CBIO, which was originally scheduled for 2030. The targets established for 2020 and 2021 were fulfilled, considering the review for 2020, promoting the commercialization of reduced emissions. Despite the non-complete fulfillment in 2022, there is no evidence that they cannot be met in the following years, just as there is no evidence that the program's goals cannot be expanded to more ambitious values. Bill 528/2020 is being processed in the Federal Senate, which increases the current 27.5% ethanol admixture in gasoline to a 35% maximum. The project also establishes a gradual increase in the mandatory blending of biodiesel into fossil diesel, reaching 20% by 2030, and with the possibility of reaching 25% by 2031. In addition to the mandatory blending instrument, the program adopts auxiliary incentive instruments, such as lower consumption taxes, tax incentives for producers and distributors, an exemption from a part of federal taxes for the sale of biodiesel, lines of credit for the development of the sugar and alcohol sector, construction of biodiesel refineries and financing for multimodal transport development. The country has added two cellulosic ethanol plants, also known as second-generation plants, to its industrial park and is carrying out tests on the co-processing of vegetable oils in two refineries, already with 10% of the refined volume (Ebadian et al., 2020).

3.2 Low Carbon Agriculture Plan

The federal government's Low Carbon Agriculture Plan (ABC Plan) includes the recovery of 15 million hectares of degraded pastures, and the integration of crop-livestock-forest (ILPF) systems in 5 million hectares by 2030, among other technological measures (Table 2). According to the Ministry of Agriculture and Livestock and Food Supply (MAPA), between 2010 and 2020, resources were raised via rural credit to recover 26.8 million hectares of degraded pastures – almost double the target. However, attempts to exceed the target for fundraising per hectare fell far short of the emissions mitigation target for technology, of which only 35% of the desired result was achieved (MAPA, 2023).

The implementation for ABC Plan included the collaboration of 116 experts from 31 institutions. Representatives from the government, civil society, the private sector and research institutes (MAPA, 2023). The legislation and instruments that regulate the program guide the adoption of actions to reduce between 1168 and 1259 million tons of CO_{2eq} per year, from the sector's total emissions, estimated at 3236 million tons of CO_{2eq} for 2020. The Plan is based on a non-mandatory instrument, encouraging rural producers to use a set of technologies and productivity processes,

reducing losses and suppressing emissions with environmental gains, adopting technologies previously established in Brazilian agriculture and livestock farming (Table 2). The plan is combined with credit instruments at lower interest rates than usual, notably for small and medium-sized rural producers.

Table 2 – Technologies adopted in the ABC Plan and their performance in the period from 2010 to 2020, Source: MAPA, 2023.

TECHNOLOGIES	AREA INVOLVED (Million hectares)			EMISSION SUPPRESSION Million tons of CO_{2eq}		
	GOAL	RESULT	RANGE	GOAL	RESULT	RANGE
Recovery of Degraded Pastures	15	26.8	179%	104	36.01	**35%**
Crop-Livestock-Forest Integration	4	10.76	269%	18 to 22	40.78	185%
Direct Planting System	8	14.59	182%	16 to 20	26.7	133%
Biological Nitrogen Fixation	5.5	11.78	214%	10	21.56	216%
Planted Forests	3	1.88	63%	-	8.82	-
Animal Waste Treatment	4.4	38.34 million ^{m3}	871%	6.9	59.81	867%
ABC Plan TOTAL	**35.5** million ha	**54.03** millions ha	**152%**	**133 to 163**	**193.67** million tons of CO_{2eq}	**119%**

The ABC Plan also seeks to increase rural producers' income, improve rural property infrastructure and environmental compliance of production. From 2010 to 2020 it attained 54.03 million hectares throughout Brazilian national territory, half of which were declared to be for pasture recovery. The general plan reduced 193.67 million tons of GHG, given in $MgCO_{2eq}$, which was almost 20% above the general target (MAPA, 2023). However, in relation to the mitigation of GHG emissions from livestock farming, the main type of emission from the agricultural sector, when illegal deforestation is excluded, it fell short of achieving its targets, according to official data shown in Table 2, as the main reduction potential in the sector is the recovery of degraded pastures.

4. Discussion

The advocacy for the effectiveness of mandatory instruments, whether command-and-control or market-based, is far from unanimous. According to Jänicke (2017), governments should play a crucial role not in establishing standards, limits, or enforcement measures, but rather in setting ambitious climate policies and assuming responsibility for outcomes. National governments, the author argues, can incentivize subnational and municipal governments, promote action through the dissemination of successful practices and technologies, stimulate competition, and build expert networks, all while directing policies and incentives toward economic and non-economic benefits achievable through initiatives.

However, according to Wagner and Ylä-Anttila (2018), Peel et al. (2019), Mishra and Sing (2019), Ebadian et al. (2020), Eskander and Fankhauser (2020), Schroeder and Kobayashi (2021), McDonald and McCormack (2021), and Pirard et al. (2023), state regulatory and control action should be broadly considered. Mandatory regulatory frameworks, which imply the compulsory adoption of programs and actions at both subnational and local levels as well as in key economic sectors, can be more effective than voluntary market-based instruments. Pirard et al. (2023) suggest that decentralized and hybrid climate governance—combining public instruments with voluntary private initiatives—should be solely provisional, preceding robust government policies. According to this author, climate policies are likely to fail unless strict laws and regulations are enforced across institutional levels and among various stakeholders.

In this context, by enacting Law 13,576 in 2017, which establishes the National Biofuels Policy, the Brazilian government has demonstrated its commitment to achieving annual GHG emission reduction targets through mandatory regulations for the fuel production chain (ANP, 2022). Seven years after the law's enactment and with only six years remaining until the 2030 deadline, there is no indication that biofuel integration targets in Brazil's energy chain will not be met. The mandatory regulatory framework may be critical in achieving national targets by requiring fuel distribution companies to participate, setting clear goals, and enforcing compliance through sanctions for non-fulfillment.

The success of the biofuels program is a key factor in any analysis aimed at decarbonizing Brazil's vehicle fleet. The most favorable scenario involves expanding the use of electric vehicles, alongside increased use of ethanol in light internal combustion vehicles. The fuel is regarded as the most sustainable source, with the Renovabio program considered pivotal (Glyniadakis and Balestieri, 2023). In their discussion on vehicle fleet electrification and the adoption of energy efficiency improvement instruments, Moreira et al. (2022), and Gauto et al. (2023) also emphasize the importance of the biofuels program alongside electrification efforts. They advocate for policies that promote production incentives.

Energy security and rural economic development have been drivers of mandates for the blending of biofuels and fossil fuels. Brazil, Canada, Japan, the Netherlands, South Korea, Sweden and the United States have each adopted them. For Ebadian et al. (2020), wherever the mandates do not increase, production remains constant. In New Zealand and South Africa, where no mandatory blending has been adopted, the biofuels market has not been consolidated. Japan, with no mandate for biodiesel blending, and South Korea with no mandate for alcohol, have not seen the market consolidate for each of these biofuels. Nonetheless, the authors emphasize, mandates were not sufficient in other countries, limited by a lack of raw materials, competing costs, absence of refineries, risks to food security, or obstacles to changes in land use.

Conversely, regarding the emissions reduction plan for agriculture, Article 6 of Decree No. 7,390 of 2010 mandates that voluntary actions be adopted to meet the national commitment described in Article 12 of Law No. 12,187/2009. This commitment aims to reduce emissions by 1,168 to 1,259 million tons of CO_{2eq} out of a projected total of 3,236 million tons of CO_{2eq} emissions for the sector in 2020. The plan relies on financial incentives to encourage the adoption of established technologies and processes in the sector, previously outlined in Table 2. While the primary goal is to reduce GHG emissions, the plan also seeks to increase farmers' incomes and improve the environmental sustainability of production. Over ten years, it has covered 54.03 million hectares across the country, reducing GHG emissions by 193.67 million tons, measured in $MgCO_{2eq}$ (MAPA, 2023).

For Carauta et al. (2021) the ABC Plan holds the main line of credit to finance the sector's decarbonization; however, it still falls well short of reaching its potential due to the low channeling of this credit for core activities, in the recovery of degraded pastures. The majority of family or medium-sized properties—around 70% of Brazilian rural properties (EMBRAPA Rondônia, 2023)—lack resources for medium and long-term investments in pasture division, and in genetic improvement of the herd, and as a consequence of pasture division, face an increase in the number of drinking fountains and mineral salt troughs. The ABC Plan permits the use of financial resources for these activities indirectly linked to pasture recovery (Silva et al. 2018). This situation imposes difficulties on the sector's most significant opportunity to reduce emissions, as livestock farming shows the highest emissions, and the greatest opportunities for suppression or removal are in the retention of carbon in the soil in quality-managed pastures, as half of Brazilian pastures suffer from some degree of degradation (Damian et al., 2021).

At lower levels, but not negligibly so, are emissions from the management of waste from animals raised in confinement, notably from part of dairy farming in the Brazilian context. In the Atlantic Forest biome, non-irrigated pastures managed at medium and high stocking fixed more carbon than their cattle production emitted. In this context and under specific soil and rainfall conditions, they presented negative net CO_{2eq} emissions, a phenomenon credited to greater root development and better maintenance of the soil biota. The type of soil management, the average capacity per hectare, and the rainfall regime were decisive for a positive balance, possibly because emissions due to changes in land use no longer occur significantly in this Brazilian biome (Oliveira et al, 2020).

5. Conclusion

The biofuels program, supported by a mandatory blending instrument, combined mainly with tradable carbon certificates, but also with tax incentive instruments and technology use, show effectiveness in achieving the announced GHG emissions reduction targets. However, the non-mandatory incentive policy of the Low Carbon Agriculture Plan (ABC Plan), combined with credit instruments at lower interest rates than usual, was not effective in achieving its goals of recovering degraded pastures, the sector's main reduction potential.

There is no evidence that Renovabio's progressive goals will not continue to be achieved over the next few years and cannot yet be expanded. There is a bill under discussion to increase blending mandates. The same, however, does not occur for the targets and potential of recovering degraded pastures, despite the volume of credit capture available, as the traditional rural credit mechanism in use allows the use of resources in the property's infrastructure, such as the division of pastures, or the installation of salt troughs and drinking fountains, due to the division of pastures and genetic improvement of the herd.

Expanding biofuel blending mandates and including the aviation and maritime transportation sectors are represent opportunities to render the transportation sector's GHG reduction targets more ambitious. For agriculture, in addition to the need to put a stop to illegal deforestation and to rethink the amount of deforestation permitted by law, one of the paths might be the adoption of mandates for slaughterhouses and dairies to incorporate, within their supplies, meat and milk coming from properties with lower GHG emissions, whether or not ordered through tradable carbon certificates, as is the case with biofuels. Mandates for slaughterhouses and dairy products, and valuing the reduction of emissions from livestock farming, in addition to climate gains, can be development instruments for small to medium-sized livestock farmers, and even for large ones. Due to their potential, these deserve additional feasibility studies.

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Ethics Approval

Not applicable

Conflict of interest

The authors declare no conflict of interest.

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