A Economia numa Perspectiva Interdisciplinar 3

Elói Martins Senhoras
(Organizador)

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APRESENTAÇÃO

O campo científico da Economia surge como um dos grandes expoentes da emergência do movimento Iluminista no século XVIII e desde então tem passado por diferentes revoluções e movimentos epistêmicos que procuraram, tanto, fomentar uma construção científica autônoma, quanto, engendrar interações com outros campos do pensamento humano.

Tomando como referência uma abordagem absorvente e relacional, o presente livro, “A Economia numa Perspectiva Interdisciplinar 3”, vem corroborar com o campo epistemológico de Economia no Brasil e em Portugal a partir de uma agenda de estudos que se fundamenta na pluralidade de vozes e discursos.

Resultado de trabalho coletivo de diferentes pesquisadoras e pesquisadores portugueses e brasileiros, oriundos das macrorregiões Sul, Sudeste e Norte, este livro traz uma rica pluralidade de debates e análises que fortalecem a compreensão interdisciplinar existente no campo epistemológico da Economia.

Organizado em treze capítulos, as pesquisas presentes nesta obra foram estruturadas com base em um convergente método dedutivo, no qual partiu-se de marcos de abstração de modelos, teorias e análises históricas até se chegar à análise empírica específica da realidade concreta e dos respectivos objetos de estudo.

A natureza exploratória, descritiva e explicativas dos capítulos caracterizou-se por uma abordagem quali-quantitativa que partiu dos procedimentos de revisão bibliográfica e documental no levantamento de dados, combinada ao uso de técnicas de hermenêutica e modelagem econômica, bem como análise gráfica e geoespacial na interpretação dos dados.

Na construção interdisciplinar do conhecimento, comandada pelo olhar econômico, cinco eixos temáticos se destacaram, permitindo aglutinar as análises e discussões dos treze capítulos, por meio de recortes teóricos relacionados aos ramos da Economia Solidária, Economia do Trabalho, Economia Urbana e Industrial, Economia Organizacional e Economia Monetária e Financeira.

Com base nas análises e discussões apresentadas nesta presente obra, composta por treze capítulos e cinco ramos teóricos, subsídios são apresentados para uma apreensão interdisciplinar do campo científico de Economia findando explorar à luz de um olhar descritivo e prescritivo a complexa realidade em suas interações no dinâmico tripé Homem-Mercado-Estado.

Em nome do grupo diversificado de profissionais envolvidos neste livro e comprometidos com o avanço do campo científico de Economia, convidamos você leitor(a) a desbravar tradicionais e novas reflexões à luz de uma abordagem interdisciplinar que valoriza o diálogo e a pluralidade na abordagem de nossa complexa realidade empírica, rica de desafios para o pensamento e a reflexão.

Excelente leitura!

Elói Martins Senhoras

SUMÁRIO

CAPÍTULO 13

THE ROLE OF SUGARCANE ETHANOL IN BRAZILIAN CO_2 EMISSIONS

Data de aceite: 01/06/2020

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RESUMO: Este trabalho considera a perspectiva ambiental-econômica da produção de etanol de cana-de-açúcar no Brasil, e desenvolve um modelo para quantificar a relação entre emissões de CO_2 brasileiras e a produção de etanol no período 1990-2018. Um modelo log-log de regressão múltipla é utilizado. Variáveis independentes incluem preço do petróleo, produção de etanol e PIB per capita. Concluiu-se que cada aumento de 1% da produção de etanol de cana-de-açúcar leva a uma redução de 0.165% das emissões de CO_2, *ceteris paribus*. Este trabalho sugere que a produção de etanol contribuiu para reduzir as emissões de CO_2 brasileiras, e que a produção de etanol de cana-de-açúcar pode tornar-se um importante veículo para mais abatimentos num futuro próximo.

PALAVRAS-CHAVE: biocombustíveis, etanol de cana-de-açúcar, redução de emissões de CO_2, energia.

ABSTRACT: This paper addresses the environmental-economic perspective of sugarcane ethanol production in Brazil and develops a model to quantify the relationship between Brazilian CO_2 emissions and ethanol production in the period 1990-2018. A double-log multivariate regression is used. Explanatory variables include price of oil, ethanol production and GDP per capita. It was found that every one-percent increase in sugarcane ethanol production leads to a 0.165% decrease in CO_2 emissions, *ceteris paribus*. This research concludes that ethanol production has contributed to reducing Brazilian CO_2 emissions, and that sugarcane production might become an important vehicle for further abatements in the near future.

KEYWORDS: biofuels, sugarcane ethanol, CO_2 emissions reduction, energy.

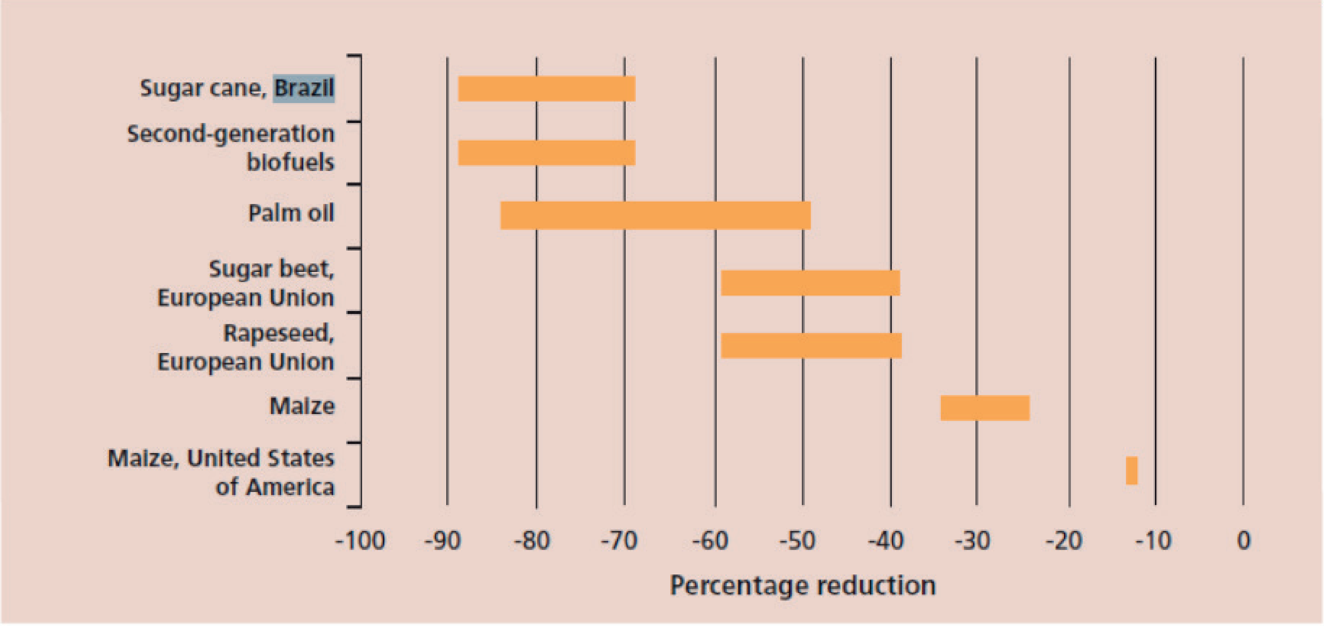
INTRODUCTION

Brazil is the largest producer of sugarcane ethanol (Sparovek, Berndes, Egeskog et al, 2007, p.271). Brazil is also the lowest-cost producer of ethanol. It is estimated that the country would be the only one capable of producing ethanol "even if crude oil prices fell to $39 per barrel" (Tokgoz & Elobeid, 2006, p. 6). Brazilian 2018-2019 total ethanol production totaled 33.1 billion litters, which is nearly three times more than what was produced in 1990-1991 (UNICA, 2019). Amongst other reasons, the increase in production was necessary in order to support the advent of flex fuel vehicles (FFV) – which run solely on ethanol, gasoline or a mixture of both – in 2003. Considering the 2003-2009 period, the production of light vehicles (cars and light commercials) increased 5,058.24% (ANFAVEA, 2010, p. 64).

In 2008 ethanol exceeded gasoline consumption, and in 2009 the sugarcane industry was responsible for 18% of the country's energy mix, being the second most important energy source after petroleum and its derivatives (Chaddad, 2010, p. 174).

Not only is sugarcane environmentally friendly, it is more efficient at reducing greenhouse gas (GHG) emissions than alternative kinds of ethanol, such as corn-based ethanol. Considering gasoline as a criterion, corn ethanol reduces emissions by 10 to 30%, whereas sugarcane ethanol reaches nearly 90% (IEA, 2010, p. 21).

Figure 1: Reductions in greenhouse gas emissions of selected biofuels relative to fossil fuels
Source: IEA, 2010



Note: Excludes the effects of land-use change. *Sources:* IEA, 2006, and FAO, 2008d.

It is estimated that 600 million tons of CO_2 have not been emitted due to the use of sugarcane ethanol since 1975 (Chaddad, 2010, p. 174). However, there is still concern about how the increasing demand for biofuels might lead to deforestation, which would minimize or cancel the gains obtained (Barr, Babcock, Carriquiry et al, 2010, p. 1).

Therefore, the following question is addressed: has the production of sugarcane ethanol contributed to reducing Brazilian CO_2 emissions? A double-log multivariate regression model is used to determine the correlation between CO_2 emissions and ethanol production. Other explanatory variables include GDP per capita, price of oil, deforestation rates, vehicles fleet, and size of the cattle herd.

ETHANOL IN BRAZIL

Historically, most economic problems in Brazil have been a consequence of disturbances in its balance of payments (Bonelli & Malan, 1976, p. 353). In 1973, similarly to several countries, Brazil was dependent on oil imports. Oil consumption rose from 21 million m^3 in 1967 to 46 million in 1973, when Brazil imported nearly 81% of its oil needs (Herman, 2005, p. 95). Oil prices skyrocketed and, in spite of the abundance of petrodollars, which were able to safeguard economic growth in the short term, it became clear that the situation was unsustainable. At the time, the cost of oil imports represented half of the revenue from Brazilian exports (Goldemberg, 2006, p.1).

Hence, in 1975, the government decided to launch ProAlcool, a program created to alleviate the country's dependence on increasingly costly oil imports and as a protection against fluctuation of sugar prices (Matsuoka, Ferro & Arruda, 2009, p. 373). The main objective was to substitute gasoline consumption with sugarcane ethanol (Soccol, Vandenberghe, Costa et al, 2005, p. 897). During its first two phases, the government had a pivotal role on creating the basis of what would become a successful experience 35 years later. From 1975 to 1979, command and control actions were taken and anhydrous ethanol was blended with gasoline. From 1979 to 1985, the second phase, incentives were provided for investments in distilleries and mills to expand sugarcane capacity, as well as in the development of ethanol-fuelled vehicles – vehicles capable of running on 100% hydrous ethanol. The third phase, which happened from 1985 to 1990, was characterized by a decline in oil prices that made ethanol too expensive comparatively to gasoline. In 1989, sugar prices rose and there was a shortage of ethanol in the country, which undermined consumers' trust in the renewable fuel. Sales of ethanol-fuelled vehicles, which represented 76% of cars sold in 1986, dropped to less than 1% by 1997. In 1999, the industry was deregulated and ethanol price setting was abandoned. It was only during its fifth phase, started in 2003, that ethanol regained consumers' confidence and was boosted by the advent of flex-fuel vehicles, which are subject to tax incentives not offered to regular vehicles (Soccol, Vandenberghe, Costa et al, 2005, p. 898; FAO, 2008, p. 24-25; Matsuoka, Ferro & Arruda, 2009, p. 374; Elobeid & Tokgoz, 2006, p. 6-7).

Nowadays, since 2015, there is still a mandate of 27% anhydrous ethanol blending to all petrol sold by petrol stations, a 20% *ad valorem* duty is charged on ethanol imports that exceed the tariff quota, and the taxes on gasoline are greater than the ones on ethanol. However, the sugarcane market in Brazil has no other major regulation and works in a close-to-market condition. (Elobeid & Tokgoz, 2006, p. 7; FAO, 2008, p. 25; Tokgoz & Elobeid, 2006, p. 9; Sparovek, Berndes, Egeskog et al, 2007, p.276).

Source: IEA, 2010

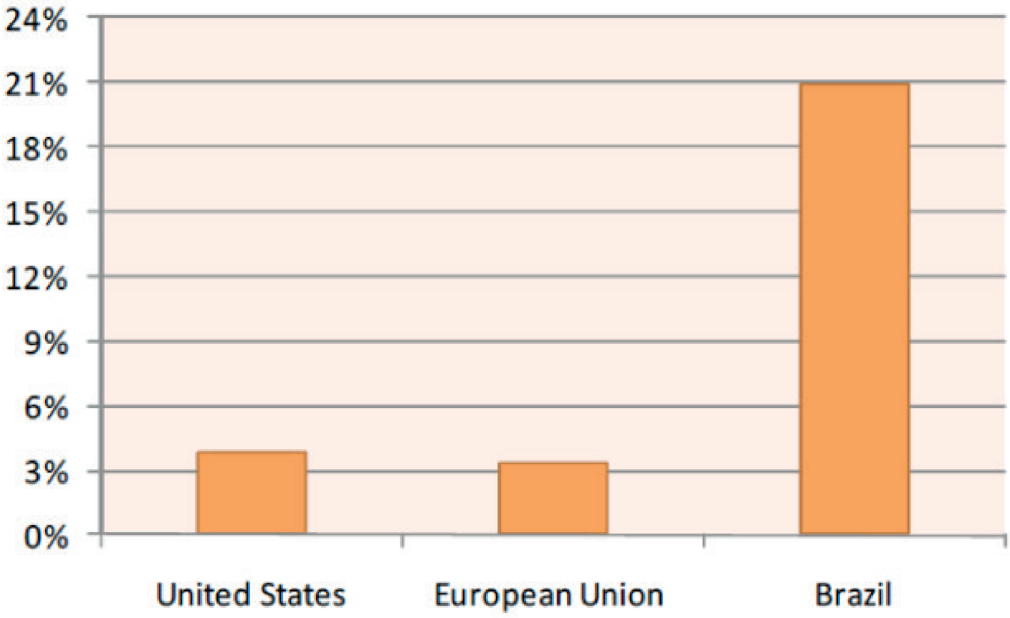


Figure 2: Share of biofuels energyin road transport (2008)

Some of the reasons why Brazil has been so successful are the substantial fleet of flex-fuel vehicles, economies of scale, the lowest production costs in the world (in 2005, fixed and variable costs were estimated at about U$0.21 and U$0.89 per gallon, respectively), technological advancements, frequent use of the bagasse – a sugarcane by-product that provides enough energy to make modern mills self-sufficient concerning energy –, and facing no constraint to increase sugarcane plantations, since sugarcane area planted represents 3% of the total available area (Elobeid & Tokgoz, 2006, p. 8, 10; Matsuoka, Ferro & Arruda, 2009, p. 374-375).

Much of the international concern in regards to increasing ethanol production is related to how it might affect food prices. However, instead of competing with crops such as soybeans and corn, the past decades have seen an increase in sugarcane cultivation at the expense of pastures and cropland. The authors are unable to conclude if sugarcane production impacts food prices, even though they affirm this could happen, and mention that the production of tomatoes, peanuts and oranges was reduced during the 2005-2006 harvest due to an increase in sugarcane production (Smeets, Junginger, Faaij et al, 2008, p. 787; p.794). On the other hand, more optimistic studies, such as Matsuoka, Ferro & Arruda's (2009, p. 375), affirm that sugarcane could only have little, if any, impact on food production due to the 232 million of hectares available.

Another frequent concern is that sugarcane might lead to deforestation in the Amazon. Nevertheless, there are two major obstacles to these theories: recent Brazilian legislation – it is forbidden to grow sugarcane in areas such as the Amazon forest and the Pantanal – and biological limitations, since the Amazonian weather and soil are not adequate for sugarcane (Martinelli & Filoso, 2008, p. 886).

APPROACH AND METHODOLOGY

In order to determine the relationship between CO_2 emissions and ethanol production, a double-log multivariate linear regression model is used. Data refer to the 1990-2018 period, and were collected from different sources. It is important to acknowledge that the small number of observations is a limitation of this study, yet it is present due to lack of data. CO_2 emissions data were obtained from Global Carbon Atlas. Deforestation rates, size of cattle herd, fleet of vehicles, ethanol production and GDP data were obtained from OBT/INPE (Earth Observation General Coordination/National Institute for Space Research), IBGE (Brazilian Institute of Geography and Statistics), DENATRAN (National Traffic Department), UNICA (Brazilian Sugarcane Industry Association) and The World Bank, respectively. Data for oil prices were collected from EIA (Energy Information Administration) and converted to constant 2010 American dollars. Missing data for ethanol production in 1990 and fleet of vehicles in the period 1990-1997 were obtained, respectively, from UPB (Uniao dos Produtores de Bioenergia) and E&E (Economia e Energia).

An increase in oil prices stimulates the demand for ethanol (Tokgoz & Elobeid, 2006, p. 4). Since higher oil prices will lead to reduced gasoline consumption and increased demand for ethanol, and since the production of ethanol emits almost 90% less CO_2 when compared to gasoline, it is feasible to conclude that oil prices are negatively correlated with CO_2 emissions. It is important to state that, in Brazil, the transport sector accounts for the largest share of CO_2 emissions from fuel combustion (IEA, 2010, p. 20), so there might be a multiplier effect associated with an increase in ethanol consumption.

Not only are most of Brazilian GHG emissions a consequence of deforestation (Cerri, Maia, Galdos et al, 2009, p. 832), but the largest source of CO_2 emissions is due to Amazon deforestation (Morton, DeFries, Shimabukuro et al, 2006, p. 14637). However, a different aspect of deforestation is also considered: the global relative share of CO_2 emissions from deforestation was smaller in 2008 than a decade before, so it is believed that carbon savings brought about by reduction in deforestation might be lower than expected, particularly if we consider the substantial increase in carbon emissions from fossil fuel combustion in the same period (Van der Werf, Morton, DeFries et al., 2009, p. 737-738). Despite the uncertain magnitude, a positive correlation between deforestation and CO_2 emission is expected.

The size of cattle herd is expected to matter for four reasons: first, it is the main deforestation driver in the Brazilian Amazon (Rivero, Almeida, Avila et al, 2009, p. 41), contributing indirectly to CO_2 emissions. Second, cattle emit CO_2 as part of their metabolic function. Third, much of the land is cleared and burned – emitting more CO_2 – to create pastures. Finally, fossil fuels are used for heating and feedstock production (Lutz, 1998, p.

291). Even though a positive correlation is expected, it might happen that it is not a strong one, since it is only the third contributor in Brazilian GHG emissions, more significantly responsible for CH_4 rather than CO_2 emissions (Cerri, Maia, Galdos et al, 2009, p. 835; Garnett, 2009, p. 493).

Ethanol production is expected to have a negative correlation with CO_2 emissions because of its relatively higher efficiency in regard to fossil fuels. Most of the arguments that support this idea have been mentioned in the previous sections. One of the main expectations for the future is that ethanol production will continue not competing with food crops or forests, but eventually compete with pasture (Chavez-Rodriguez & Nebra, 2010, p. 9255). This might have another multiplier effect, since pasture creation is caused by cattle ranching, the main deforestation driver, which is, in turn, the major source of CO_2 emissions in Brazil.

The fleet of vehicles is used as an explanatory variable in the model not only to represent the demand side, but also because “CO_2 is the dominant source of GHG emissions from an automobile and the level of CO_2 emissions from automobiles is directly linked to vehicle fuel consumption” (An & Sauer, 2004, p. 20). This variable is expected to be positively correlated with the dependent variable.

GDP is believed to be positively correlated with CO_2 emissions. There is a plethora of inconclusive studies about what the maximum point is where income becomes high enough to make CO_2 emissions start declining (Moomaw & Unruh, 1997, p. 452, p. 462), but most of the time correlation is positive (Tucker, 1995, p. 219).

The theoretical model is then specified as:

$$\mathbf{CO_2 = f\,(P\overset{-}{O}IL,\ DE\overset{+}{F}OR,\ CA\overset{+}{T}T,\ ET\overset{-}{H}AN,\ VE\overset{+}{H}IC,\ G\overset{+}{D}P)}$$

This can be represented by the following equations:

$$\mathbf{Y = \beta_0 - \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 - \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + E}$$

$$\mathbf{CO2 = \beta_0 - \beta_1 POIL + \beta_2 DEFOR + \beta_3 CATT - \beta_4 ETHAN + \beta_5 VEHIC + \beta_6 GDP + €}$$

Year	Price of Oil[1] (POIL)	Deforestation[2] (DEFOR)	Size of Cattle Herd[3] (CATT)	Ethanol Production[4] (ETHAN)	Fleet of Vehicles[5] (VEHIC)	GDP[6] (GDP)	CO$_2$[7] (CO2)
1990	35.87	13,810	147,102,314	11,920	13,864,931	1.190	207
1991	29.26	11,130	152,135,505	11,515	14,173,415	1.208	217
1992	28.61	13,786	154,229,303	12,722	14,477,916	1.202	218
1993	23.72	14,896	155,134,073	11,729	14,927,365	1.258	228
1994	21.65	14,896	158,243,229	11,292	15,646,335	1.325	240
1995	22.76	29,059	161,227,938	12,752	16,630,332	1.384	256
1996	27.11	18,161	158,288,540	12,611	17,748,327	1.414	281
1997	24.67	13,227	161,416,157	14,395	18,942,339	1.462	297
1998	16.29	17,383	163,154,357	15,415	24,361,347	1.467	308
1999	22.53	17,259	164,621,038	13,876	27,172,139	1.474	316
2000	35.28	18,226	169,875,524	12,983	29,722,950	1.539	324
2001	29.46	18,165	176,388,726	10,592	31,913,003	1.560	333
2002	29.63	21,651	185,348,838	11,536	35,523,633	1.608	327
2003	33.59	25,397	195,551,576	12,623	36,658,501	1.626	318
2004	43.37	27,772	204,512,737	14,736	39,240,875	1.720	334
2005	59.99	19,014	207,156,696	15,389	42,071,961	1.775	342
2006	69.53	14,286	205,886,244	15,821	45,372,640	1.845	342
2007	75.28	11,651	199,752,014	17,844	49,644,025	1.957	357
2008	98.82	12,911	202,306,731	22,527	54,506,661	2.057	380
2009	62.46	7,464	205,307,954	27,526	59,361,642	2.054	360
2010	79.61	7,000	209,541,109	25,691	64,817,974	2.209	411
2011	108.98	6,418	212,815,311	27,376	70,543,535	2.297	430
2012	107.29	4,571	211,279,082	22,682	76,137,191	2.341	460
2013	102.54	5,891	211,764,292	23,226	78,310,730	2.411	495
2014	91.78	5,012	212,366,132	27,476	86,700,490	2.423	524
2015	48.02	6,207	215,220,508	28,480	90,686,936	2.337	495
2016	39.64	7,893	218,190,768	30,232	93,867,016	2.260	454
2017	48.26	6,947	215,003,578	27,254	97,091,956	2.284	464
2018	62.10	7,536	213,523,056	27,859	100,746,553	2.310	457

[1] Source: EIA (http://www.eia.gov/). Brent spot price FOB (constant 2010 US$ per barrel);
[2] Source: OBT/INPE (http://www.obt.inpe.br/). Annual deforestation rate (km^2);
[3] Source: IBGE (http://www.sidra.ibge.gov.br/). Number of livestock (cattle);
[4] Sources: UNICA, 1991-2018 (http://www.unica.com.br/); União dos Produtores de Bioenergia, 1990 (http://www.udop.com.br/). Total ethanol production (1000m^3);
[5] Source: DENATRAN, 1998-2018 (http://www.denatran.gov.br/); Economia e Energia, 1990-1997 (http://www.ecen.com/);
[6] Source: The World Bank (https://data.worldbank.org/). GDP (trillions, constant 2010 US$);
[7] Source: Global Carbon Atlas (http://globalcarbonatlas.org). CO$_2$ emissions (MtCO$_2$).

Table 1: Data used

Two different regressions were considered. The baseline specification, which was described above, yielded the following results:

```
      Source |       SS           df       MS      Number of obs   =        29
-------------+----------------------------------   F(6, 22)        =    182.57
       Model |  230970.725         6  38495.1208   Prob > F        =    0.0000
    Residual |  4638.72366        22  210.851076   R-squared       =    0.9803
-------------+----------------------------------   Adj R-squared   =    0.9749
       Total |  235609.448        28  8414.62315   Root MSE        =    14.521
------------------------------------------------------------------------------
         CO2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         GDP |    381.257   47.04009     8.10   0.000     283.7019    478.8122
       VEHIC |   .3202023   .5292598     0.61   0.551    -.7774153     1.41782
       ETHAN |  -.0048898   .0013147    -3.72   0.001    -.0076163   -.0021634
        CATT |  -1.352286   .4186561    -3.23   0.004    -2.220526   -.4840467
       DEFOR |   .0003662   .0008536     0.43   0.672    -.0014041    .0021366
        POIL |  -.7841221   .2419138    -3.24   0.004    -1.285821   -.2824236
       _cons |   30.59295   53.15964     0.58   0.571     -79.6534    140.8393
------------------------------------------------------------------------------
```

The first step was to verify how statistically significant from zero the estimated coefficients were. At a 5% level of significance, one-sided t-Tests were applied for each of the coefficients, but VEHIC (0.61 < 1.77) and DEFOR (0.43 < 1.77) produced large p-values, indicating weak evidence against the null hypothesis. Particularly, deforestation's statistical significance was surprisingly low, which could mean that it has indeed accounted for an unprecedented smaller share of total emissions. Furthermore, in regard to the vehicle fleet, it is likely to be strongly correlated with a country's GDP. Thus, variance inflation factor (VIF) values were calculated and a Pearson's product-moment correlation was run in order to check for multicollinearity. Since VIF values were very large for both VEHIC (31.3; r(27) = 0.96) and CATT (14.53; r(27) = 0.94), and because there are only a few observations available, a second regression with fewer variables was estimated in order to increase the degrees of freedom.

In addition to ETHAN, the variables considered in the refined baseline model were those which are the most widely accepted as explanatory variables to predict CO_2 emissions according to the relevant literature: POIL and GDP.

```
      Source |       SS           df       MS      Number of obs   =        29
-------------+----------------------------------   F(3, 25)        =    253.71
       Model |  228116.734         3  76038.9114   Prob > F        =    0.0000
    Residual |  7492.71418        25  299.708567   R-squared       =    0.9682
-------------+----------------------------------   Adj R-squared   =    0.9644
       Total |  235609.448        28  8414.62315   Root MSE        =    17.312

------------------------------------------------------------------------------
         CO2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
         GDP |    302.865   25.20263    12.02   0.000     250.9592    354.7708
       ETHAN |  -.0034342   .0012637    -2.72   0.012    -.0060368   -.0008316
        POIL |  -.7903268   .1952241    -4.05   0.000    -1.192398   -.3882552
       _cons |  -89.10887   21.02424    -4.24   0.000    -132.4091   -45.80863
------------------------------------------------------------------------------
```

The coefficients varied slightly and their signs remained the same, as expected. Furthermore, all the coefficients are statistically significant at the 5% level.

A double-log form was then used to provide an interpretation in terms of percentage change. Hence, the suggested model found to most accurately describe Brazilian CO_2 emissions is the following:

$$\ln Y = \beta_0 - \beta_1 \ln X_1 + \beta_2 \ln X_2 + \beta_3 \ln X_3 + E$$

$$\ln CO2 = \beta_0 - \beta_1 \ln POIL - \beta_2 \ln ETHAN + \beta_3 \ln GDP + €$$

```
  Source |       SS           df       MS      Number of obs   =        29
-------------+----------------------------------   F(3, 25)        =    326.39
       Model |  1.97277173         3  .657590576   Prob > F        =    0.0000
    Residual |  .050368865        25  .002014755   R-squared       =    0.9751
-------------+----------------------------------   Adj R-squared   =    0.9721
       Total |  2.02314059        28  .072255021   Root MSE        =    .04489

------------------------------------------------------------------------------
        lCO2 |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
        lGDP |   1.546654   .1032118    14.99   0.000     1.334085    1.759223
      lETHAN |  -.1652655   .0573341    -2.88   0.008    -.2833473   -.0471838
       lPOIL |  -.1250456   .0262985    -4.75   0.000    -.1792084   -.0708828
       _cons |   7.049816   .5275482    13.36   0.000      5.96331    8.136322
------------------------------------------------------------------------------
```

The data suggest that the relation between CO_2 emissions and ethanol production can be described by the following equation:

$$\ln CO2 = 7.05 - 0.125 \ln POIL - 0.165 \ln ETHAN + 1.547 \ln GDP$$

This means that for every 1% increase in ethanol production, *ceteris paribus*, Brazilian CO_2 emissions decrease by 0.165%.

CONCLUSION AND IMPLICATIONS

Ethanol production might have been, therefore, one of the factors that contributed to reducing Brazilian CO_2 emissions in the past two decades. Most important, as demand for biofuels grows both domestically and internationally, ethanol production is expected to continue to increase and become responsible for a largest share of CO_2 abatement in the country during the coming years. Another important aspect to be considered in the future is that carbon sequestration could be applied to sugarcane ethanol combustion, which could theoretically lead to negative CO_2 emissions (Schrag, 2007, p. 812).

Even though the percent change caused by an increase in ethanol production is relatively small, if the country is able to maintain its high expansion rates – there was a 18% increase between 2014 and 2013, which might represent a 3% abatement in CO_2 emissions, according to the proposed model –, reductions might prove to be significant in the long run. As more countries start shifting their demands away from fossil fuels and towards biofuels, including ethanol, worldwide production of sugarcane ethanol, led by Brazil, might increase at an increasing rate, thus decreasing CO_2 emissions at a faster pace.

Moreover, a considerable amount of CO_2 emitted during the sugarcane cycle is still caused by straw burning, a technique used as part of the harvesting process. There is, nevertheless, a law that demands requires straw burning in mechanical harvesting areas to be 100% eliminated by 2021, and in non-mechanical harvesting areas the deadline is in 2031 (Smeets, Junginger, Faaij et al, 2008, p. 790), which is another reason to believe that further reductions are possible in the near future.

The major implication of this study is to add a quantitative approach to describe the relationship between CO_2 and sugarcane ethanol production, which can prove useful to policymakers in Brazil and elsewhere. It is also expected that the results obtained from this model lead to a better acceptance of Brazilian ethanol in world markets, and hopefully that they raise awareness of the importance of biofuels as a tool for fighting increasing global CO_2 emissions.

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