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Are Geographical Indications contributing to sustainability? The case of coffee industry and deforestation in Colombia

Nicola Caravaggio[1] and Cristina Vaquero-Piñeiro[2]

Abstract

Colombia accounts for more than 300 years of history in coffee production, for a leading position in the global market and for the majority of national land dedicated to this production. In the early 2000s, *Café de Colombia* was certified as Geographical Indication (GI) to differentiate it, preserve local traditional expertise and support sustainable farm practices. Nonetheless, would it have happened in the absence of GI certification in terms of environmental sustainability, and of forest cover change? This paper estimates the effects of GI on deforestation by adopting the Synthetic Control Method on a country-level panel dataset over the 1992-2020 period. Results show that the GI quality schemes has brought changes in deforestation rates with a reduction in the short term but followed by a new uprising in the long term. The paper can help guide the implementation of development strategies addressing sustainability from different perspectives and the design of more resilient agricultural policies.

Keywords: Deforestation, coffee, Geographical Indications, Colombia, Synthetic Control Method

JEL codes: Q150, Q180, Q230, N560, C330

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1 Introduction

Colombia is, together with Brazil, one of the two world leaders producing, consuming, and exporting countries of coffee (FNC, 2011). Although with a decreasing trend over the last decades, more than 800 thousand hectares of national land are still dedicated to this crop, mainly managed by artisanal and family farmers. Coffee remains among the primary agriculture productions in Colombia and a cornerstone of national economy and identity.

Over the decades, however, the role and the relevance of coffee production radically changed shifting from an agricultural commodity to a differentiated product. After the elimination of the International Coffee Agreement in 1989, the coffee market became more and more competitive, and the place of origin have been enriched by a crucial dimension for coffee quality and reputation (Marescotti and Belletti, 2016). The protection of the origin's name of green coffee has therefore turned out to be crucial. To preserve the identity of coffee coming for this country, and differentiate it from others, in December 2004 *Café de Colombia* was nationally certified as a Geographical Indication (GI) and in 2007 it was the first extra-EU product recognised within the EU GI quality scheme (Quiñones *et al.*, 2015).[3]

GI is a sign used on agri-food products that have a specific geographical origin and possess qualities and reputation that are essentially or exclusively due to a particular geographical environment, made of natural and human factors. Recalling the *terroir* principle coined for the wine sector, territorial attributes, which are specific to a place and heterogeneously distributed, contribute to the perceived quality and the reputation for the product's quality (Josling, 2006). Several are the socio-economic benefits generated by GIs that incentive producers to request for the acknowledgment: premium pricing (Duvaleix *et al.*, 2021), farmers' income (Hughes, 2009), consumers' preferences (Menapace *et al.*, 2011), trade (Curzi and Huysmans, 2022; De Filippis *et al.*, 2022), and local development (Takayama *et al.* 2021; Crescenzi *et al.* 2022). More recently, GIs have been enriched by a potential key role for an integrated sustainability (environmental, social, and economic) (Vandecandelaere *et al.*, 2020). Even if sustainability is not one of the direct aims of GIs, the regulative nature of this quality scheme gives some concrete opportunities by amending the Product Specification (PS) to make productions more sustainable and fairer.[4] Existing papers have however mainly investigated sustainability issues through a supply-chain approach focusing on the environment friendly strategies that producers could implement, while rare are the contributions that examine this issue from a territorial perspective questioning about which might be the effects of such scheme on environmental resources and dynamics, such as land-use changes. The mandatory production location within the region of origin could, in fact, generates some negative externalities especially because, as stated by Marescotti and Belletti (2016), in the case of coffee "countries GIs usually don't show much interest in inserting too specific production rules or environmental constraints" [p. 12].

In this paper, we investigate one specific nature of environmental sustainability effects of GIs by looking at coffee production in Colombia and testing whether the acknowledgment of the GI *Café de Colombia* in December 2004 have influenced national deforestation patterns. With this aim, we use

[3] Nowadays we have more than 280 GIs produced in non-EU countries. Among them there is only another coffee production that is the Café de Valdesia from Dominican Republic recognised in 2016.
[4] The Product Specification is the official document with the specific conditions of production of the GI. The right to use a GIs belongs to producers located within the region of origin defined, who comply with the Product Specification.

a Synthetic Control Method (SCM) approach on a country-level panel dataset over the 1992-2020 period.

The effect on forest pattern represents an issue of primary interest for our analysis given that forests, from various perspectives, are recognized as a key ingredient for sustainable development in Latin America. Forests are one of the most important natural resources in Latin America which hosts about one third of worldwide tropical forests (Blackman *et al*., 2014). They always played a crucial role in determining societies' evolution and community well-being as source of primary and non-primary goods (Bakkegaard *et al*., 2017; Ros-Tonen and Wiersum, 2003) while playing a fundamental role in providing ecosystem services, supporting environmental sustainability and fighting climate change (Kramer *et al*., 1997; Lugo, 1997; Houghton *et al*., 2000; Cunningham *et al*., 2015; Wiśniewski and Märker , 2019).

Results show that the GI quality scheme has brought changes in deforestation rates, positive in the short term, but negative in the long term.

With this paper, we provide the first empirical casual estimation of the ex-post effects of GIs at the territorial level on deforestation trends. Few studies exist that investigate the effects of GI on forest projections, but, to the best of our knowledge, no one has adopted casual empirical methodologies before. For instance, Ingram *et al*. (2020) use data from interviews, market surveys and ethnography to look at the case of the white honey from the Kilum-Ijim forest, in the Cameroon Highland, finding that, despite the aim of protecting forest, deforestation continued after certification.

By providing quantitative evidence, we also contribute to the GI literature discussing about extra-EU GIs, which is still scarce in comparison with papers on EU GIs, and specifically about *Café de Colombia*, product that was the mainly topic of quantitative research (*e.g.*, Marescotti and Belletti, 2016; Quiñones-Ruiz *et al*., 2016).

Evaluating the effects of GIs from an environmental sustainability perspective provides a welcome basis for policy debate at both national and international level. On the one hand, it rises awareness about the local-level mechanisms through which agri-food policies, in principle prioritizing local environmental and human peculiarities and uniqueness, could legitimate deforestation practices and land changes if not well designed and managed. On the other hand, in the light of the next reform of GI regulations expected in the next few years, it warns the EU of the potential integrated effects of such scheme at the global level.

The remainder of this paper is organised as follows. Section 2 and 3 detail the contextual framework guiding this paper, which are the history of coffee production in Colombia, its link with forests and the institutional background of GIs. Section 4 introduces the empirical setting, while Section 5 presents the results together with some robustness checks. Conclusions provide some policy implications.

2 Institutional background

2.1 The relevance of coffee in Colombia

Coffee arrived in Colombia in the 18th century introduced by Jesuits and over the decades has become the most widespread agriculture production of the country. Nowadays, Colombia is the second biggest coffee producer in the world behind Brazil, with coffee accounting for the 15% of the national agriculture gross domestic product (GDP) (FNC, 2011). In 2020, the production amounted to nearly 14 million 60-kilogram bags, the double of the production in 2012. More than 500,000 people are employed in the coffee production – 95% of whom cultivate farms smaller than 5 hectares. The first part of the coffee supply chain is, in fact, characterised by smallholder coffee growers, mainly family farmers or small-scale farms. Conversely, roasters, traders and distributors are mainly few international corporations operating in high-income countries (Marescotti and Belletti, 2016; Barjolle *et al*., 2017).

Colombia is a country that has also a great tradition in the export of coffee: it is one of the biggest coffee exporters and, at the same time, coffee is the country's main export. Coffee exports are mainly characterised by the higher quality and certified coffee, leaving lower quality products for internal markets. Although nowadays some of the best coffee is available locally, there still are some economic and educational accessibility barrier in domestic market. In particular, according with the quality upgrading effect theorised by trade economic literature, producers are more prone to export the highest quality products given that they can sell them in international markets at higher prices while minimizing fixed trade costs (Bauman, 2004).

To institutionally regulate the market, foster exports and stop the trade dependence from international freight companies, in the 1930s the National Federation of Coffee Growers (FNC) was established firstly and then, in the 1940s the national freight company called Flota Mercante Gran colombiana followed. In the fifties, after a severe decrease of coffee price due to an excessive world supply, the FNC realized the importance of informing consumers from where coffee comes from, and Colombia became the first coffee-producing country to implement a common strategy of differentiating and marketing its product. At the same time, several institutional farmers' training programmes have been organised during the 1960s and the 1970s to both educate farmers, informing them of new technologies and production standards, and maintain high-quality. Over the years the claim "Colombian coffee" has become a guarantee of quality and the strategy of preserving their authenticity continued along the decades. In the early 1980s a specific trademark was registered (*i.e.*, Juan Valdez).[5] Thereafter, in December 2004 the FCN presented the application to certify the *Café de Colombia* as a GI that has been nationally ratified in less than three months thanks to an astounding institutional support (Barjolle *et al*., 2017). The legal aspects of coffee's GIs are detailed explained by Quiñones-Ruiz *et al*. (2015). To guarantee the validity of the GI at the international level, in 2005 Colombia applied for certified *Café de Colombia* under the EU GI scheme as a non-EU product. The EU formal approval arrived in 2007 when the EU recognised this product as a Protected Geographical Indication (PGI).[6] *Café de Colombia* was the first non-EU agri-food products recognised by the EU and it is still today the only Colombian product recognised by the EU.[7]

2.2 Geographical Indications

The GI quality scheme was established at the early 1990s by the European Commission (EC) to protect the name of local high-quality agri-food products whose characteristics are linked to the place where they are made, the so-called region of origin. Even if distinguishing local high-quality productions from standardized ones and reducing information asymmetry between producers and consumers remain the main aim of this scheme, over the years several are the positive socio-economic

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[5] To obtain a license to use the Juan Valdez trademark, a product must consist of 100% Colombian coffee and meet quality standards stipulated by the coffee growers' federation.

[6] At the EU level among GIs, we can distinguish between Protected Geographical Indications (PGI) and Protected Designation of Origin (PDO). PDOs are the GIs with the strongest link given that raw materials and ingredients need to come from the same region of origin and every part of the production process must be located within that area. Conversely, in the case of PGIs some stages can take place outside the region of origin, or some raw materials can come from another area. According to the EU regulation, extra-EU products can instead certify only as PGI.

[7] In other countries, such as the US, Colombia maintains the use of trademarks to protect its product.

territorial externalities that literature has associated to GIs. Among them, literature provides evidence on the capacity of increasing agricultural added value (Cei *et al*., 2018), supporting population growth and employment rate in rural areas (Crescenzi *et al*., 2022), and preserving the international competitiveness of niche products (Teuber, 2010; Mulik and Crespi, 2011). There is a consensus in the literature on the fact that GIs generate positive effects also in international markets by supporting trade, increasing prices in foreign markets, and protecting products from fraud and misleading competition (De Filippis *et al*., 2022).

At the international level, GIs works as a collective property right within the Non-Tariff Measures (NTMs) framework (UNCTAD, 2019) becoming a contentious issue in trade negotiations. Since 2007, the EU has extended the scheme to extra-EU products and some of them are nowadays explicitly listed in bilateral and multilateral trade agreements (Curzi and Huysman, 2022). Due to the increasing relevance of sustainability issues, over the last years, scholars have started to investigate the effects of GIs in this context (Gocci and Luetge, 2020; Belletti *et al*., 2017). The contribution of GIs is especially debatable not only for environmental sustainability goals, such as agrobiodiversity, organic, and sustainable agriculture, but also for social and economic ones by supporting rural development and promoting better working conditions (FAO, 2021; Vandecandelaere *et al*., 2020). In addition, Galli *et al*. (2020) underline that, even if "traditional" not necessarily means less processed and heathier food, GIs could play a key role also in supporting the need for healthier diets as part of the transition to sustainable food systems. Certainly, there might be a heterogeneity among GIs' effects and performances depending on the products and countries under analysis (Vaquero-Piñeiro, 2021). Regarding coffee, several are the contributions focusing on GI coffee production worldwide. Insights from Dominican Republic are provided by Galtier *et al*. (2013), for Indonesia by Neilson (2008) for Kenyan coffee by Bagal *et al*. (2013) or Giovannucci *et al*. (2009) for Kona coffee in the US. About Colombia, Chabrol *et al*. (2017) and Quiñones-Ruiz *et al*. (2016) found that the formal acknowledgement as a GI is successful only if implemented in tandem with good institutions and practitioners knowledgeable in adopting these regulations. However, although a several studies dealt with these issues, econometric studies, especially empirical analyses of the impacts of GIs on environmental sustainability at the territorial level, are rather scarce.

3 Forests and coffee areas in Colombia

Although in recent years the trend in losses for tropical forests seems to have undertaken a decreasing trend – starting from 2016 –, there still is where most of the global deforestation occurs. In 2021, 11.1 million hectares of tree cover were losses of which 3.75 of primary forests.

Colombia is covered for more than half (53.3%) of its surface by forest area, hosting 8% of the entire Amazon Rainforest (FAO, 2022; Hansen *et al*., 2013). It represented the sixth in terms of forest losses in 2021 with more than 128,000 hectares, mostly concentrated in the Amazon and Andean regions of the country (GFW, 2023).

The country could be divided into five main biogeographical regions: Caribbean, Pacific, Andes, Amazon, and Orinco (Chaves and Arango, 1998). The two regions of Andes and Amazon is where most the Colombian forest is concentrated. The Amazonia region hosts the largest extent of Colombian forest and, although being sparsely populated, is where is located the most active colonization front of the state (Rodríguez *et al*. 2012). The Andean region follows with a forest coverage of more than 9 million of hectares, representing the most densely populated area of the country – hence where the colonization first started – and where, unfortunately, only less than 40%

of natural cover remains (Rodríguez *et al*., 2006). The Amazon region showed the highest forest loss between 2013 and 2018 with 6,344 km^2 followed by the Andean region with 3,677 km^2 (González-González *et al*., 2021).

The mountain Andean area of Colombia in where coffee plantations are located representing the area of primary interest for our analysis. Although there has been an increasing interest for global and country-level analysis of deforestation, especially through the increasing availability of satellite data, still the general attention in the Latin America region is dedicated to lowland tropical forests, primarily the Amazonian basin. Nonetheless, mountains not only represent a large area in this region (Myers *et al*. 2000) but they also are source of greater ecosystem services through their influence on the hydrological cycle and source of water for population – living both in lowlands and mountain areas (Gomez-Peralta *et al*. 2008). Andes represent the largest mountain extension in South America crossing vertically the region for more than 8,000 km, stretching from Venezuela to Chile. They are home of about 40 million inhabitants and for this reason they play an important economic and ecological role for these countries (Armenteras *et al*., 2011). In Colombia the Andes area represents about 25% of the country's surface hosting 70% of the entire population (Armenteras and Rodrigues, 2007) characterized by an urbanization process antecedent to the Hispanic period and where coffee plantations, one of the main crop productions in this area, undoubtedly affected this specific ecosystem.

Due to their peculiarities, Amazon and Andean regions are also characterized by different drivers of deforestation. In the Amazon region the work of Armenteras *et al*. (2013) identified as main drivers' cattle activities and rural density, followed by altitude, presence of protected areas, and forest fires. For the specific Andean region, instead, Armenteraas *et al*. (2011) investigated separately mountain and lowland areas between 1985 and 2005. The reduction of forest for the whole area was equal to 0.67% (more than 1.47 million of hectares) and for the largest share (63%) concentrated in the mountain region, where coffee plantations are primary located. Deforestation in the Andean Mountain areas results to be driven primary by economic activities, presence of protected areas, and higher slopes. Conversely, for lowland areas deforestation is more related to rural population, pasture and crop productions, presence of protected areas, and increase in temperature. Moreover, the authors stress how mountain forests in Colombia are in a more advanced stage of exploitation since their colonisation occurred before that for lowland areas.

Which are the main drivers of deforestation in Colombia is a debating question. One of the important instances within this issue is surely linked with the long-lasting conflict within the FARC (Revolutionary Armed Forces of Colombia) movement and the Colombian government. While the enlargement of the territories controlled by the guerrillas represented a deterrent which led to a phenomenon of land abandonment (Sánchez-Cuervo *et al*., 2012) – followed by forest reconversion – or obstacle to infrastructure development (Murillo-Sandoval *et al*., 2020), they also exacerbated illicit cropping and land grabbing operations – also in protected areas – within occupied territories (Negert *et al*., 2019; Clerici *et al*., 2020). Eventually, with the end of the conflict the peace achieved in 2016 (MADR-UPRA, 2014) followed the National Agricultural Frontier (NAF), the program aimed at identifying territorial spaces for both rural agricultural developments as well conservation areas. However, the recent work conducted by González-González *et al*. (2021) demonstrates that agricultural activities represent a factor of primary role, even if with different implication among regions. Furthermore, through a spatially-explicit modelling platform, they show how distance to previous deforested area as well as administrative areas attract deforestation. For the specific Andean region also distance to roads and urban and rural centres act as enhancement of deforestation.

Coffee cultivation has had a significant impact on the environment in Colombia, particularly on the country's forests. In the early days of coffee production, farmers would clear forests to make way for coffee plantations resulting in negative impact on country's biodiversity such as reduction of water quality, soil erosion or loss of habitat for wildlife. Despite traditional coffee grows in the shade of natural forests – hence is suitable with agroforestry activities –, in the past 30 years new coffee variates, able to grow in full sun, have been developed. About 60% of Colombian coffee is sun-grown while in some regions the proportion exceed three quarters. Furthermore, this new variety of coffee is also characterized by a yield per hectare four time greater than that of shadow-grown coffee (FNC, 2008; Jha *et al*., 2011; Somarriba and López Sampson, 2018). Nonetheless, despite these higher yields, the other side of the medal conceal important negative environmental effects such as tree cover and biodiversity loss as well as soil erosion (Greenberg *et al*., 1997). Furthermore, these plantations are more prone to weeds and pests leading to higher need of pesticides (Ataroff and Monasterio, 1997; Babbar and Zak, 1995; Bermúdez, 1980); conversely, shadow-grow coffee benefits from natural fertilizers through forests substrates and nitrogen-fixing trees (Beer, 1988).

Taking into account the characteristics of coffee plantations in the Colombian Andean region as well as characteristics of this area, it is reasonable to assume that mostly any expansion of full sun coffee plantation would occur at the direct expense of forests. In fact, in Latin America the distance between agricultural area and forest frontier is mostly immediate with a relatively small, if not absent, degraded area – conversely to what could be observed, instead, in some Asian countries such as India (Hyde, 2012). In fact, González-González *et al*. (2021) stress how in this region land use exercises a close pressure on forests while the Andean region has been identified by Etter *et al*. (2006) as a hotspot of deforestation by investigating the role played by agricultural land use footprint in driving deforestation in Colombia.

Some papers address the effects of voluntary certifications for coffee productions on deforestation. Ibanez and Blackman (2016) find that eco-certifications foster the adoption of cleaner farm practices such as reduction in sewage disposal and the use of organic fertilizer in southeaster Colombia (Cauca department). Positive results were also identified by Rueda and Lambin (2013) which evaluated the impact of the Rainforest Alliance certification on small-scale coffee farmers in the Andean department of Santander. The certification not only favoured the adoption of eco-friendly farm practices but also increased the forest area, biodiversity and water resources. The same certification in Ethiopia lead to a reduction in deforestation (Takahashi and Todo, 2013). Eventually, positive impact of coffee certification was obtained also in Costa Rica by Blackman and Naranjo (2012). However, no studies exist that attempt to evaluates the ex-post effects of GIs on deforestation.

4 Empirical setting

To investigate what has been happened in Colombia after the acknowledgment of the *Café de Colombia* we use a novel dataset and exploit the Synthetic Control Method (SCM), considered the "most important innovation in the policy evaluation" field (Athey & Imbens, 2017) [p. 9].

4.1 Data

To implement the SCM analysis, we relied on a database that we arranged starting from an *ad hoc* reconstruction of forest cover data for 25 Latin American countries. The reconstruction used as primary source of data the latest 2020 Forest Resources Assessment (FRA) of FAO (2020) which provides data on total forest cover as the sum of natural and planted forest. FRA represents an official source of forest cover data where countries have to follow specific guidelines (FAO, 2018) to allow cross-country comparisons. For example, the minimum percentage canopy cover for the identification of forest areas is set to 10%. While FRA 2020 provides data for a relatively wide time arch which spans from 1990 up to 2020, in order to conduct a better analysis, we decided to expand the series backward. Hence, we extended the work of Caravaggio (2020a) where the reconstruction followed the approaches conducted by Meyfroidt *et al*. (2010) and Liu *et al*. (2017). For each considered country, the forest area has been reconstructed separately for natural and planted forest, then summed in the variable of total forest, resulting in a balanced panel of forest cover data from 1975 up to 2020.[8] The reconstruction has been conducted by consulting all specific country report from FRAs, FAO's Forest inventories back to fifties, national forestry inventories, and specific academic country studies. The reconstruction used fudge factors to harmonize the results with observations retrieved from several alternative sources by checking and selecting through the lens of the expected forest-cover pattern assumed by the forest transition (FT) hypothesis (Mather, 1992). Moreover, we also preferred a more realistic parabolic interpolation (De Boor, 1978) compared to the simple linear interpolation of FAO to reconstruct the series.

Because the goal of the work is to investigate the impact of coffee's GI in Colombia, we used yearly deforestation rate (Puyravaud, 2003) as main dependent variable (*DEF*). The use of deforestation rates not only provides a good indicator of environmental degradation but also allows for a better cross-country comparison avoiding stock comparisons. In fact, despite FAO's guidelines, national definitions of forest stock are quite different among countries; therefore, they may allegedly influence officials' country reports of FRA (Hyde, 2012).

The treatment variable on GI has been reconstructed by the documents downloadable from the EU official register eAmbrosia.

The dataset embodies other several variables which identify both country characteristics and socio economics drivers of forest cover change. Because agricultural area represents, especially in Latin America (Hyde, 2012), one of the main drivers of forest conversion in tropical countries (Hosonuma *et al*., 2012), we considered both the share of agricultural area (*AGR*) as well as an index of agricultural trade openness calculated as the ratio between the value of agricultural exports and imports (*AGR_OP*). Still within the role played by agricultural sector, we also included the variable of cereal yield (*CER_Y*), generally identified as a proxy to capture agricultural intensification (Barbier and Burgess, 2001). All these three variables have been retrieved from FAO (2022). Population is considered another driving factor of deforestation since it is related to pressure on natural resources like forests (Cropper and Griffiths, 1994). In Latin America demography factors associated with population growth resulted to further push colonization fronts into forest areas (Geist and Lambin, 2002; Grau and Aide; 2008; Carr, 2009). Therefore, we considered the variable of population density (*POP*) as well as the share of people living in rural areas (*POP_RUR*), where the impact on natural resources may be stronger. Even in this case the source of data was FAO (2022). The variable of gross domestic production (GDP) per capita (*GDP_CAP*) represents the core index of economic development for a country, widely used within the forest economics literature, especially through the Environmental Kuznets Curve (EKC) hypothesis (Caravaggio, 2020b). We retrieved this variable from the World Development Indicators (WDI) of the World Bank (WB, 2022) and it is expressed in constant 2015 US$. Trade openness is another core economics variable of a country which may affect in different ways the use of natural and planted forests both negatively (Angelsen and Kaimowitz, 1999; Libman and Obydenkova, 2013; Lankina *et al*. 2016; Leblois *et al*., 2017) and positively

[8] For some countries the reconstruction goes back to 1960. However, the necessity of a balanced panel led to consider 1975 as starting year.

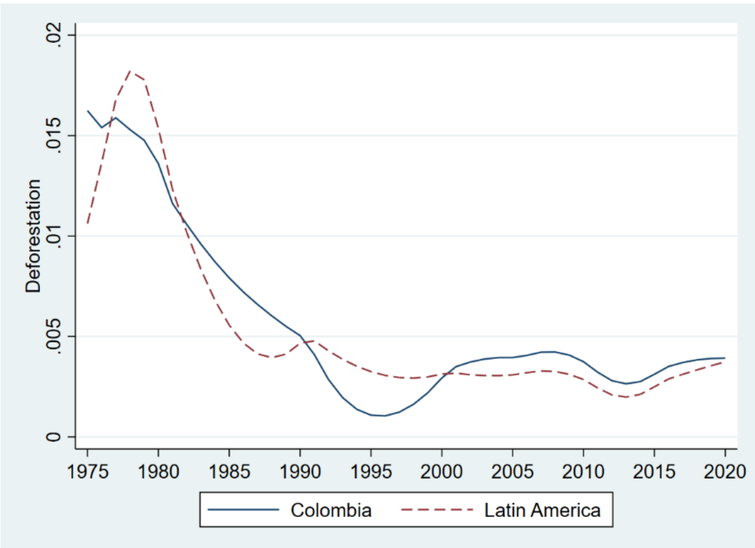
(Meyer *et al*., 2003; Niklitschek, 2007; Hyde, 2012). We proxied this variable by using the sum of import and export as share of total GDP (*TRD_OP*), as proposed from the WB (2022) from which data has been retrieved. To identify the role of institutions we relied on data provided by Freedom House (2022) where the two variables of civil liberties and political rights have been merged within a unique proxy variable which identify the quality of institutions (*INS*).[9] Good institutions are generally associated with better forest management, hence less deforestation (Bhattarai and Hammig, 2001, Murtazashvili *et al*., 2019, Cary and Bekun, 2021). Eventually, to account for the role played by climate change, we considered the variable of temperature change (*TEMP*) provided by FAO (2022) which aggregates at country level monthly data of mean temperature anomalies with respect of a baseline climatology corresponding to the period 1951-1980.

4.2 Synthetic Control Method

The SCM is a counterfactual approach for policy evaluation to estimate the impact of a treatment on a single unit in panel data settings (Abadie *et al*., 2010). It creates a synthetic control unit for the observation under analysis (Colombia in our case) to simulate via a data-driven approach what the outcome path of a single treated unit would be if it did not undergo a particular policy (GI). The synthetic unit is obtained by combining and weighting the characteristics of a group of control units, the so-called donor pool. Units including in the donor pool has, in fact, he role of "donating" the values of their observable characteristics to construct an artificial Colombia that follows similar pre-trends of the real Colombia, but that in 2005 has not certified *Café de Colombia* as a GI.

The use of such methodological approach in this paper is firstly justified as we have a single treated unit, secondly as Colombia has a different trend in outcomes variable with other Latina American countries even in the years prior to the GI acknowledgment.

Figure 1. Deforestation trend, Colombia *vs* Latin America.



Notes: the group of Latin America is composed by: Argentina, Bolivia, Barbados, Belize, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominica, Dominican Republic, Ecuador, El Salvador, Grenada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela.

[9] The two variables of the Freedom House (2022) both span from 1 to 7 where 1 is the highest level (*i.e.*, high civil liberties and/or high political rights) while 7 the lowest. The variable used in our analysis is a rescaled sum of these two variables which spans from 1 to 10 (where 1 is the lowest institutional quality level and 10 the highest).

First, we identified with 2005 the treatment year, given that since 2005 (the application was sent in December 2004) the *Café de Colombia* has been recognised as a GI and distinguish between pre- (1992-2005) and post- (2005-2020) treatment period. We selected 1992 as the first pre-treatment year because it was when the EU food GI quality scheme came into force and extra-EU countries started to replicate and adopt the same scheme nationally. Second, we selected the set of socio-economic, cultural and environmental factors measured at the country level that literature and stylised facts have identified as forest cover change determinants (see section 5.1 for the discussion and Table A 1 for definitions). Third, we selected the control group (the donor pool).[10] It need to be composed by countries that are comparable with the country under analysis, but that have never implemented a policy similar to the one under analysis (a GI certification for coffee).
To select it, we started from the entire list of 25 Latin American countries and then we discard the following group of countries. Firstly, we did not consider small islands and tax heaven' countries due to the fact that in these areas forest cover might have benefitted or lost from their characteristics unrelated to forest issues (*e.g.*, remote locations or economic conditions). Second, we eliminated countries for which relevant data are missing and Dominican Republic since in this country there is a similar policy: the *Cafè of Valdesia* has been acknowledged as a GI in 2016. According to the SCM assumptions, to guarantee for the validity of the final control group (16 countries), we checked that the trends of the outcome variable in the treated country and in the donor pool were similar and that the values of pre-treatment predictors in the treated unit was neither the largest or the smallest of the sample (Table A 2).

From the donor pool, the SCM algorithm weighted all the observables for the synthetic control of Colombia. The comparison between the pre-treatment average values of covariates used to create the synthetic counterfactual with the average of Colombia and the average of the donor pool is summarised on Table A 3.

This paper is one of the few studies that use a SCM to estimate the effects of different events on forest projections. Sills *et al.* (2015) studied the effects of local initiatives on the gross deforestation in Brazil (*i.e.*, loss of mature forest), Rana and Sills (2018) the impacts of forest management certifications on tropical deforestation, while Amador-Jimenez *et al*. (2020) the impact of Covid-19 lockdown on forest fires in Colombia. Most recently, Cappelli *et al*. (2022) used the SCM to estimate whether the implementation (in the national constitution) of the *Buen Vivir* principles has proved effective in reducing forest losses in Bolivia.

5 Results

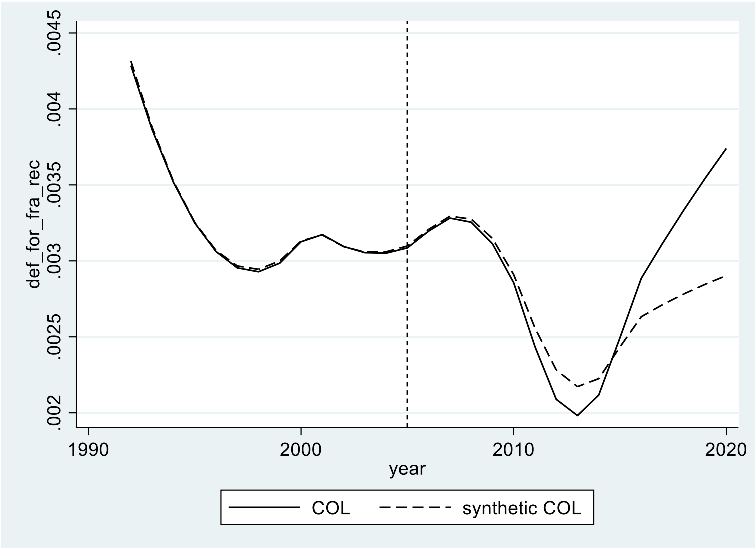
Findings are reported in Figure 2 depicting the trajectories of treated and synthetic counterpart. The dotted line shows the outcome for synthetic Colombia estimated as a counterfactual of what would have been observed for the affected unit in the absence of the intervention (see Table A 4 for the weights donated by each country of the donor pool). For the years before the beginning of the policy

[10] Control variable used to create the counterfactual Colombia are agricultural area, population density, people leaving in rural areas, trade openness, cereal yield, temperature change, GDP per capita, house of freedom index, agricultural trade openness.

in 2005, trajectories are similar, while since the 2005 onward a difference between Colombia and the synthetic unit emerges.

The graph shows that, all as equal, without the acknowledgment of *Café de Colombia* as a GI, this country would have experienced a worse increase in deforestation rates. However, in the long-run the effect declined over time suggesting that the agricultural area continued to expand even with higher rates compared to the synthetic Colombia without the GI policy. Overall, the impact is around 0.2 percentage point.[11] Henceforth, the adoption of GI scheme for the coffee it seems to have led to a sustainability spill-over effect in terms of less deforestation in Colombia, but only in the short-term.

Figure 2. Deforestation trend, Colombia *vs* synthetic Colombia.



Although we cannot precisely test in favour of which destination is the land-change at the expense of forest, we can adopt the same SCM to investigate the effect of such certification on national coffee production (as share of total crop production) which reflect the upward trend of demand. Data show, in fact, that the reputation and the demand for Colombian coffee has constantly increased over time with a consequent higher pressure on local production and land use.[12] Data from the International Coffee Organization (ICO) show that consumption in the Colombian domestic market grew 5.6% in coffee year 2020/2021 (ICO, 2021). An increase of demand might generate a request for more agricultural land at the expense of forests.

With this analysis we considered as our response variable *COF*, identifies as the green coffee production (in tonnes) over total crop production. We derived this variable from FAO (2022).

Figure 3 shows that the GI acknowledgment generated an increase in coffee production higher than what Colombia would have experienced without the GI (see Table A 5 for weights donated). Certainly, not all the coffee produced in Colombia will be certified. The higher pressure in terms of land destination is therefore not only related to an increase in the production of GI *Café de Colombia,* but it can be driven also by standard (not certified) coffee plantations. In this context, it is arguably

[11] To quantify the impact of the treatment we refer to the difference after treatment between the treated and the synthetic cohort. It is calculated as the difference between the 2020-2005 difference in Colombia and the 2020-2005 difference of synthetic Colombia.

[12] For instance, the main famous producer Colombia's Juan Valdez has opened its first brick-and-mortar coffee shop in Argentina, marking the chain's 14th international market.

that the quality of the *Café de Colombia* generates positive externalities for all the Colombian coffee productions benefitting from the reputation of the certified production in a sort of free-riding condition.

Part of this increasing demand of Colombian coffee can be realistically driven by the inclusion of *Café de Colombia* within the EU list in 2007. Being a GI recognised within the official EU quality scheme might have some consequence in increasing reputation, foreign demand, and exports and, consequently, more pressure on forest management. Therefore, we decide to adopt the same approach to evaluate whether the recognition of this GI by the EU has had additional effects on Colombia's forest cover changes. Results are provided by Figure 4 and Table A 6 showing that, compared to the synthetic unit, without the inclusion in the EU official register, Colombia would have followed a different deforestation pattern, characterized by lower deforestation rates.

Figure 3. Coffee production, Colombia *vs* synthetic Colombia – coffe production.

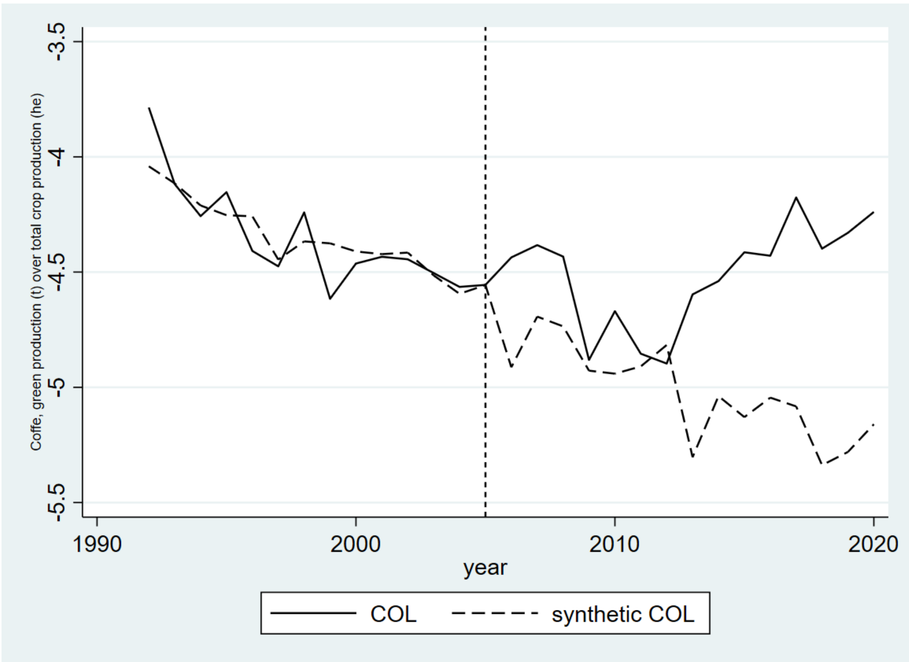
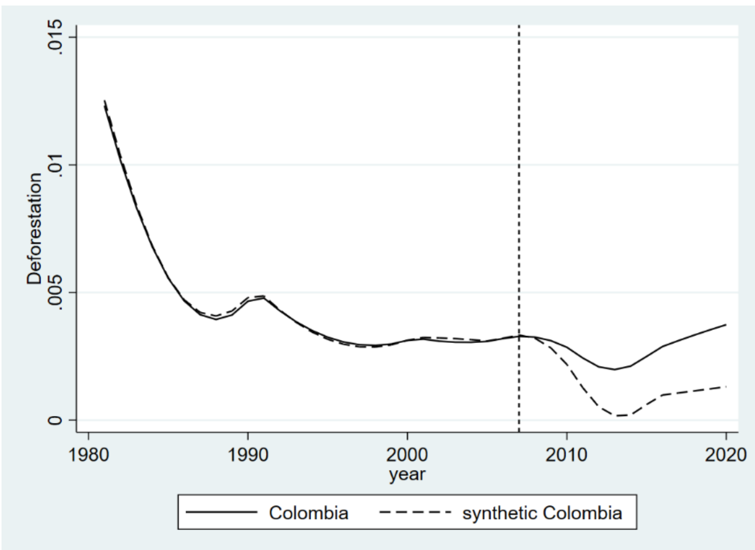


Figure 4. Deforestation trend, Colombia vs synthetic Colombia – 2007 EU registration.



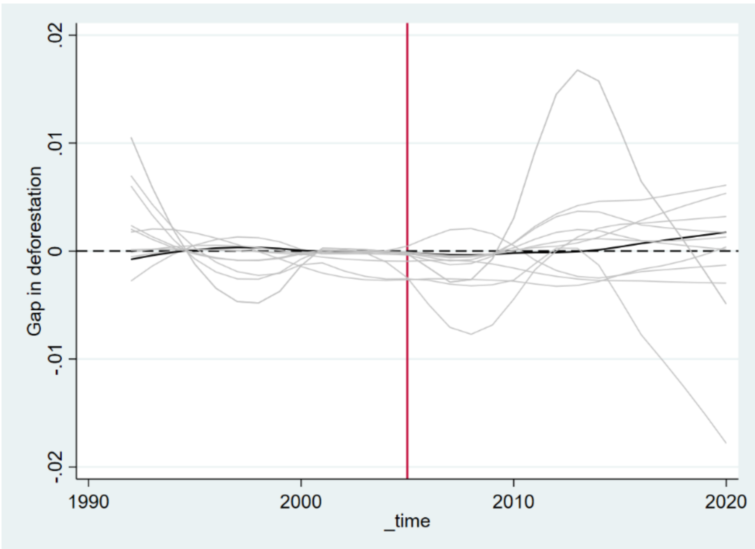
Notes: Treatment year set as 2007.

Tu sum, over the years, the protection of *Café de Colombia* within the GI quality schemes has brought changes in deforestation rates, positive in the short term, but negative in the long term. Conversely, for the real Colombia, the coffee production increases more than for the synthetic one. Arguably, our results highlight the difficulties of agri-food oriented policies in addressing deforestation, and more in general environmental sustainability issues. Indeed, also in the case of GI that is a quality-oriented policy rather than a productive one, institutions seem to effectively not pursue a coherent change in forest use trends.

5.1 Robustness analysis

In order to check the validity of our results we conduct several robustness checks. First of all, we run a placebo test, commonly used in SCM literature, by iteratively replicating the SCM for every other state that did not certified coffee productions as a GI during the sample period (Abadie and Gardeazabal, 2003; Bertrand *et al*., 2004; Abadie *et al*., 2010). Results show that overall, the gap estimated for Colombia is large relative to the gaps for the states without GI (Figure 5). During the years, in fact, the gap becomes progressively far from 0, meaning that Colombia was capable of reducing deforestation thanks to the GI only in the short-run.

Figure 5. Trends in deforestation in Colombia (treated country) and placebo gaps.



Notes: the grey lines represent the difference in deforestation between each state in the donor pool and the respective synthetic control; the bold black line represents the gap between Colombia and its synthetic country.

Thereafter, we replicate the baseline model by excluding from the donor pool Brazil, which represent the first Latin America coffee producer. Agriculture production, as well as deforestation trends, in countries neighbouring Brazil, like Colombia, might have been affected by Brazilian informal cross-border displacement of agri-food productions and exports (Meyfroidt *et al*., 2010). Over the last decades, in fact, Brazil has expanded coffee exports to Colombia to meet the increasing domestic demand. Most of Colombian coffee production is in fact intended for export, aimed at markets that pay better. At the same time, results could be biased by the fact that Brazil accounts alone for more than 40% of forests in Latin America (FAO, 2020). Figure A 1 and Table A 7 show that our main results are robust.

Findings are coherent also when we replicate the analysis considering (i) the inclusion of all the discarded states in the donor pool (Figure A 2, Table A 8) and (ii) the exclusion of countries for which data on coffee green harvested and production are not available (Figure A 3, Table A 9). Results are consistent also for the model re-estimated the model by considering the entire available time variability (1982-2020) (Figure A 4, Table A 10).

Lastly, we conduct two other tests. The first one regards the forest data selection and consists in replicating the model by using a different source of forest cover data while the second rely in the application of a Difference-in-Differences (DiD) approach (Abadie, 2005) to validate our findings.

Although FAO remarkably enhanced the quality of forest dover data along different editions of FRAs (MacDicken, 2015) after receiving several critiques regarding their reliability (Grainger, 2008; Hansen *et al*., 2013), it still represents an official source directly provided by states, hence possibly prone to subjectivity. Furthermore, the nature of data, which necessary requires interpolation, could mask some important dynamics occurring in relative short time spans (Schwartz *et al*., 2020). Therefore, to further validate our result, we performed the analysis by using a different source to identify forest cover data and, consequently, to calculate our dependent variable of deforestation rate. Hence, we used the Climate Change Initiative land cover (CCI-LC) databased implemented by a joint work of the European Space Agency (ESA, 2017) with the Catholic University of Louvain. CCI-LC data is composed by 220 different land cover classes with a spatial resolution of 300 meters with 1992-2020 as time-span coverage. To identify the category of forest coverage of our interest we used the SEEA (System of Environmental-Economic Accounting) (UN, 2014) land cover reclassification (composed by 14 classes), hence we combined the following two categories: tree-covered areas and mangroves. The former category comprises geographical areas dominated by natural tree plants with a coverage of at least 10%, hence both natural and management forests. The latter category includes areas with a woody vegetation with 10% coverage of more, but regularly flooded by salt and/or brackish water. Data, aggregated at national level, has been retrieved from FAO (2022).

Satellite sources are becoming more and more used in forestry literature while at the same time they increase their reliability. For example, among other sources we may mention the Global Forest Watch (GFW, 2023) database, based on the work of Hansen *et al*. (2013), as one of the most widely used sources, characterized by a spatial resolution of 30 meters. However, this source provides data only for forest losses and its time span, which starts only on 2001, would not allow to have a proper pre-treatment period. Even the MODIS-LCCS (Sulla-Menashe *et al*., 2019) or the European Copernicus Global Land Service (CGLS) (Buchhorn *et al*., 2020) databases suffers from a short time coverage, respectively 2001-2020 and 2015-2019. Eventually, the satellite source provided by Liu *et al*. (2020) and based on the Global Land Surface Satellite (GLASS), although characterized by a larger time span, 1982-2015, it has a far higher spatial resolution, equal to 5 kilometres. Therefore, we preferred the CCI-LC source because able to balance detailed spatial resolution with a suitable time span.

The analysis conducted with the use of deforestation rates obtained from CCI-LC (Figure A 5 and Table A 11) shows a similar pattern compared to the baseline scenario suggesting that using different sources to account for forest cover data, hence avoiding any possible issue related to FAO's data reliability (interpolation, different evaluation of forest stock or countries' subjectivity), lead to a similar conclusion where the introduction of the GI *Café de Colombia* halted deforestation in the short-run while showing a higher raise in the long-run. It is important to stress that with this different source the positive initial impact of the policy extends compared with our baseline scenario with FRA data. Moreover, we also conducted the same test by using non reconstructed FRA forest cover data (FAO, 2022). Even in this case results (Figure A 6 and Table A 12) do not differ from the baseline scenario.

With the second and final test related to our estimations procedure, we tested the validity of our empirical setting and results by adopting the following dynamic DiD approach (1) over the 1992-2020 period:

$$DEF_{it} = \alpha + \beta_1(Post_{it} \cdot GI_{it}) + \beta_2(Post_{it}) + \beta_3(GI_{it}) + Controls_{it} + \delta_t + \delta_r + \varepsilon_{it} \qquad (1)$$

where the interaction term between $Post_{it}$ (a dummy referring to the post-2005 GI acknowledgment) and GI_{it} (a dummy taking value one for Colombia) is our key variable. It captures the before and after *Café de Colombia* GI certification. $Controls_{it}$ is the control matrix accounting for the same explanatory variables used in the SCM added with year dummies and year-country fixed effects. The interaction term is statistically significant and positive which stresses how the policy effectively affected deforestation (Table 1). Nonetheless, although positive, the coefficient term is low as result of the twofold effect of GI implementation of deforestation: negative (reduction) in the short-run and positive (increase) in the long-run.

Table 1. Difference-in-Difference estimates.

DiD Model	
Café de Colombia (Post*GI)	0.0007*** (0.000)
Post	✓
GI	✓
Controls	✓
Year-country dummies	✓
Year dummies	✓
Observations	530
Groups	19
R-squared	0.90

Notes: ***p < 0.01, **p < 0.05, *p < 0.1; outcome variable is expressed in terms of share. The variable *Controls* includes: agricultural area; population density; people living in rural areas; trade openness; GDP per capita; cereal yield; temperature change; house of freedom index; agricultural trade openness; year dummies; year-country fixed effects. Driscoll and Kraay (1998) robust standard errors in parentheses (Hoechle, 2006).

6 Conclusions

Over the decades, Colombian coffee was gradually losing its commodity nature with several reputation criteria emerging on the market. To differentiate a raw production as coffee in a more and more competitive and globalised market, producers' country needed to rely on unrelocatable features. Territorial peculiarities (environmental and mankind) become thereby crucial assets and GIs the most promising single origin certification scheme to adopt. Several are the contributions evaluating the relationship between coffee farming and socio-economic impacts of GIs for producers (ICO, 2019), while are still rare empirical evidence on territorial effects, especially in the case of sustainability issues. The linkages with forest projections have for instance never been investigated before. This paper is the first study that examines this issue by looking at what would have been forest projections in Colombia without the acknowledgment of GI. Results highlights that the institutionalisation through the GI scheme have had a significant and positive effect in terms of deforestation halting in the short terms, but negative in the long one. Therefore, how a century-old food tradition such as coffee could ensure a sustainable future for Colombia remains an open question. This paper gives us the opportunity of reflecting about the strengths and threats of such scheme with the aim of identifying potential key areas of policy intervention to promote a more forest-oriented management of certified coffee production.

Starting from the more general consideration, GIs could represent a valid policy tool to strength the forest sustainable expansion of the coffee section in a market-based context. Through the amendment of PS, a more environmental-friendly production process could be in fact promoted.

GIs, as other form of certification (Bager *et al*., 2020), represent a strategic tool to support economic sustainability by contrasting the downward trend of coffee prices (ICO, 2019). It guarantees premium pricing through product upgrading (vertical differentiation), while limiting the production intensity and controlling overproduction, which is considered the main cause of lower coffee price levels. Changes in price of coffee can have therefore a significant impact on economic and social development of local communities. However, it is important to avoid that the rising costs for reputational marketing and distribution, especially in foreign countries, decreases the local farmers' share in the coffee retail price.

At the same time, the increasing demand and the spatial concentration of production within the region of origin means that the policy action have to deal with higher stress on land use destination. Due the limitations of GIs' regulations, the easiest way to expand production area is through a reallocation of land destination within the region of origin, and therefore, very presumable at the expense of non-agricultural land, such as forests. The main contradiction of such scheme is that GIs are designed to produce within relatively small areas and reduce production intensity (yield), but yet also accelerate market and export expansion. This could yield a form of growth which may undermine their capacity to benefit sustainability if not well managed.

In this respect, a key policy line of intervention can be the support of a reorganization of local actors, mainly small-scale producers, towards new entrepreneurial opportunities (traders, processors, roasters, distributors, marketers, packaging suppliers, baristas, and so on) (Arias and Fromm, 2019). In this way, it might be possible to hypothesize a reorganisation of local economic towards added value sectors more independent from land exploitation as well as a reduction of the imbalances along the global value chains given that the main part of coffee is exported in green form and value added remain in importing countries (ICO, 2022). At the same time, more opportunities for cross-generational collaboration in contrast of the declining participation of youths in the sector can rise. Youths will play a key role in guaranteeing the future of the coffee industry and supporting the adoption of innovations and agri-environmental friendly agricultural practices (ICO, 2021). Within the GI scheme, this could be promoted by requiring territorial standards for the majority of the supply stages or by promoting horizontal form of coordination among actors. For instance, a best practice to look at is the Italian GI organization in *Consortia*.

Moving to forest management issues, deforestation is nowadays the primary threats for tropical forests, but it is not the only one. Forest degradation, climate change and the reduced amount of stored CO_2 emissions also lead to negative reverse impact on forests (Gibson *et al*., 2011; Matricardi *et al*., 2020). For this reason, an effective management of forest activities (Blackman, 2020) as well as a comprehensive GI governance strategy is crucial to guarantee that a century-old food tradition will help to ensure a sustainable future for Colombia. At the same time, this sort of institutional certification schemes needs to be compared and managed in tandem with private eco-friendly certifications (Vanderhaegen *et al*., 2018; Oberlack *et al*., 2023).[13]

Considering the high demand of coffee and the higher yield of sun-grown coffee plantations – as well as cocoa – undoubtedly makes less appetible shadow-grown plantation, those which would lead to a lower pressure on forest resources (or even a reversal positive effect on forest cover). Nonetheless, when those two approaches are profitably compared, more comprehensive economic evaluation are needed. In fact, several studies demonstrates how when all factors are taken into account (*e.g.*, income from fruit, firewood or timber, ecosystem services, and higher financial resilience), the economic return of shaded plantations exceed that of sun-based plantations. (*e.g.*, Gobbi, 2000; Bacon, 2005; Rice, 2008; Cerda *et al*., 2014; Ruf and Schroth, 2015; Haggar *et al*., 2017; Pinoargote *et al*., 2017; Jezeer *et al*., 2018). Within this literature also the role played by products certification which may represent a premium price for producers should be considered when evaluating and comparing coffee productions. GI clearly fit within this framework and, if properly applied and tailored for shaded coffee plantations, it could effectively represent a tool able to promote friendly coffee livelihoods able to even promote reforestation. However, shaded plantations could be incentivized in several ways: payment schemes directed to farmers for biodiversity conservation practices; value chain increase; development of sustainable intensification approaches; supportive legislation and incentives aimed at stimulating the adoption of shaded plantations; agroforestry activities (Somarriba and Lopez-Sampson, 2018). In fact, agroforestry systems, especially when adopted through small-scale production – such as coffee plantations in Colombia – represent an effective way to halt deforestation. It is indeed considered by Meyfroidt and Lambin (2011) as a kind of fifth pathway through nations' forest transitions.

In sum, the domestic and international demand for better quality coffee increases in tandem with stakeholders' and consumers' attention towards environmental sustainability issues, such as deforestation. GIs can have mixed impact in these direction as demonstrated by this paper in the case of forest. Upgrading efforts can be facilitated by a systematic comparative analysis of the development policies, agri-food sector regulations, and forest management strategies in force at all levels in a specific area. It increases the possibility of designing successful policy interventions to improve the socio-economic and environmental sustainability of specific productions, while operating as a catalyst of the entire local sustainable development.

Our work represents a first attempt, and a primer within its relative literature, to evaluate the possible role played by coffee GI in Colombia in strengthening (or not) forest conservations. Nonetheless, we must keep in mind we conducted a national-level analysis, hence without differentiating among territorial regions. In fact, although Andean forests – where coffee production are located – represents a deforestation hotspot, the lowland Amazon area experienced higher level of forest losses in recent years. Furthermore, also the post-peace agreement between FARCs and the Colombian government and the NAF program represent other important drivers of land use changes in this country. Nonetheless, while this broaden perspective adopted in this work could represent a limitation, it also

[13] Since 2021, the Green Coffee Company, which is the Colombia's largest coffee producer, has become the largest Rainforest Alliance-certified coffee producer of the country.

at the same time is stimulates further development in studying the role played by the recognition of *Café de Colombia* in terms of sustainability through a more disaggregated and spatial analysis. The extension of this study to a more detailed territorial level, upon data availability, is in our research agenda.

References

Abadie, A. (2005). Semiparametric difference-in-differences estimators. *The review of economic studies*, *72*(1), 1-19.

Abadie, A., Diamond, A., & Hainmueller, J. (2010). Synthetic control methods for comparative case studies: Estimating the effect of California's tobacco control program. *Journal of the American statistical Association, 105*(490), 493-505.

Abadie, A., & Gardeazabal, J. (2003). The economic costs of conflict: A case study of the Basque Country. *American economic review, 93*(1), 113-132.

Amador-Jiménez, M., Millner, N., Palmer, C., Pennington, R. T., & Sileci, L. (2020). The unintended impact of Colombia's COVID-19 lockdown on forest fires. *Environmental and resource economics, 76*, 1081-1105.

Angelsen, A., & Kaimowitz, D. (1999). Rethinking the causes of deforestation: lessons from economic models. *The World Bank research observer*, *14*(1), 73-98.

Arias, R. C., & Fromm, I. (2019). From cocoa producers to chocolatiers? Developing an entrepreneurial model for small-scale producers in Honduras. *International Journal on Food System Dynamics*, *10*(1), 38-54.

Armenteras, D., & Rodríguez, N. (2007). Introduccion. In: D. Armenteras & N. Rodríguez (Eds.) *Monitoreo de los ecosistemas andinos 1985–2005: síntesis* (pp. 15–17). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia.:

Armenteras, D., Cabrera, E., Rodríguez, N., & Retana, J. (2013). National and regional determinants of tropical deforestation in Colombia. *Regional Environmental Change*, *13*, 1181-1193.

Armenteras, D., Rodríguez, N., Retana, J., & Morales, M. (2011). Understanding deforestation in montane and lowland forests of the Colombian Andes. *Regional Environmental Change*, *11*(3), 693-705.

Ataroff, M., & Monasterio, M. (1997). Soil erosion under different management of coffee plantations in the Venezuelan Andes. *Soil Technology*, *11*(1), 95-108.

Athey, S., & Imbens, G. W. (2017). The state of applied econometrics: Causality and policy evaluation. *Journal of Economic perspectives*, *31*(2), 3-32.

Babbar, L. I., & Zak, D. R. (1995). *Nitrogen loss from coffee agroecosystems in Costa Rica: leaching and denitrification in the presence and absence of shade trees* (Vol. 24, No. 2, pp. 227-233). American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

Bacon, C. (2005). Confronting the coffee crisis: can fair trade, organic, and specialty coffees reduce small-scale farmer vulnerability in northern Nicaragua?. *World Development*, *33*(3), 497-511.

Bagal, M., Belletti, G., Marescotti, A., & Onori, G. (2013). Study on the potential of marketing of Kenyan Coffee as Geographical Indication. European Commission.

Bager, S. L., & Lambin, E. F. (2020). Sustainability strategies by companies in the global coffee sector. *Business Strategy and the Environment*, *29*(8), 3555-3570.

Bakkegaard, R. K., Hogarth, N. J., Bong, I. W., Bosselmann, A. S., & Wunder, S. (2017). Measuring forest and wild product contributions to household welfare: Testing a scalable household survey instrument in Indonesia. *Forest policy and economics*, *84*, 20-28.

Barbier, E. B., Burgess, J. C., & Grainger, A. (2010). The forest transition: Towards a more comprehensive theoretical framework. *Land use policy*, *27*(2), 98-107.

Barjolle, D., Quiñones-Ruiz, X. F., Bagal, M., & Comoé, H. (2017). The role of the state for geographical indications of coffee: Case studies from Colombia and Kenya. *World Development*, *98*, 105-119.

Bauman, Y. (2004). Shipping the good apples out: a new perspective. *Economic Inquiry*, *42*(3), 534-536.

Belletti, G., Marescotti, A. and Touzard, JM (2017). Geographical Indications, Public Goods, and Sustainable Development: The Roles of Actors' Strategies and Public Policies, World Development, 98: 45-57.

Beer, J. (1988). Litter production and nutrient cycling in coffee (Coffea arabica) or cacao (Theobroma cacao) plantations with shade trees. *Agroforestry systems*, *7*, 103-114.

Bermúdez, M. (1980). *Erosión hídrica y escorrentía superficial en el sistema de café (Coffea arabica L.) poró (Erythrina poeppigiana (Walpers) O.F. Cook) y laurel (Cordia alliodora)* [Master's thesis, CATIE, Turrialba, Costa Rica].

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How much should we trust differences-in-differences estimates? The Quarterly Journal of Economics, 119(1), 249–275.

Bhattarai, M., & Hammig, M. (2001). Institutions and the environmental Kuznets curve for deforestation: a crosscountry analysis for Latin America, Africa and Asia. *World Development*, *29*(6), 995-1010.

Blackman, A. (Ed.) (2020). *Latin American and Caribbean Forests in the 2020s: Trends, Challenges, and Opportunities*. IDB, Washington, D.C., US.

Blackman, A., & Naranjo, M. A. (2012). Does eco-certification have environmental benefits? Organic coffee in Costa Rica. *Ecological Economics*, *83*, 58-66.

Blackman, A., Epanchin-Niell, R., Siikamäki, J., & Velez-Lopez, D. (2014). *Biodiversity conservation in Latin America and the Caribbean: Prioritizing policies*. Routledge, New York, NY, US.

Buchhorn, M., Smets, B., Bertels, L., De Roo, B., Lesiv, M., Tsendbazar, N. E., ... & Tarko, A. J. (2020). Copernicus Global Land Service: Land Cover 100m: Version 3 Globe 2015-2019: Product User Manual. Zenodo, Geneve, Switzerland.

Cappelli, F., Caravaggio, N., & Vaquero-Piñeiro, C. (2022). Buen Vivir and forest conservation in Bolivia: False promises or effective change?. *Forest Policy and Economics*, *137*, 102695.

Caravaggio, N. (2020a). A global empirical re-assessment of the Environmental Kuznets curve for deforestation. *Forest Policy and Economics*, *119*, 102282.

Caravaggio, N. (2020b). Economic growth and the forest development path: A theoretical re-assessment of the environmental Kuznets curve for deforestation. *Forest Policy and Economics*, *118*, 102259.

Carr, D. (2009). Rural migration: The driving force behind tropical deforestation on the settlement frontier. *Progress in human geography*, *33*(3), 355.

Cary, M., & Bekun, F. V. (2021). Democracy and deforestation: The role of spillover effects. *Forest Policy and Economics*, *125*, 102398.

Cei, L., Stefani, G., Defrancesco, E., & Lombardi, G. V. (2018). Geographical indications: A first assessment of the impact on rural development in Italian NUTS3 regions. Land Use Policy, 75, 620–630.

Cerda, R., Deheuvels, O., Calvache, D., Niehaus, L., Saenz, Y., Kent, J., … & Somarriba, E. (2014). Contribution of cocoa agroforestry systems to family income and domestic consumption: looking toward intensification. *Agroforestry systems*, *88*, 957-981.

Chabrol, D., Mariani, M., & Sautier, D. (2017). Establishing Geographical Indications without State Involvement? Learning from Case Studies in Central and West Africa. *World Development*, 98, 68-81.

Chaves, S., & Arango, V. (1998). *Informe nacional sobre el estado de la biodiversidad Colombia 1997*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia.

Clerici, N., Armenteras, D., Kareiva, P., Botero, R., Ramírez-Delgado, J. P., Forero-Medina, G., ... & Biggs, D. (2020). Deforestation in Colombian protected areas increased during post-conflict periods. *Scientific reports*, *10*(1), 4971.

Crescenzi, R., De Filippis, F., Giua, M., & Vaquero-Piñeiro, C. (2022). Geographical Indications and local development: the strength of territorial embeddedness. *Regional Studies*, *56*(3), 381-393.

Cropper, M., & Griffiths, C. (1994). The interaction of population growth and environmental quality. *The American Economic Review, 84*(2), 250-254.

Cunningham, S. C., Mac Nally, R., Baker, P. J., Cavagnaro, T. R., Beringer, J., Thomson, J. R., & Thompson, R. M. (2015). Balancing the environmental benefits of reforestation in agricultural regions. *Perspectives in Plant Ecology, Evolution and Systematics*, *17*(4), 301-317.

Curzi, D., & Huysmans, M. (2022). The impact of protecting EU geographical indications in trade agreements. *American Journal of Agricultural Economics*, *104*(1), 364-384.

De Boor, C. (1978). *A practical guide to splines*. Springer-Verlag, New York, NY, US.

De Filippis, F., Giua, M., Salvatici, L., & Vaquero-Piñeiro, C. (2022). The international trade impacts of Geographical Indications: Hype or hope?. *Food Policy*, *112*, 102371.

Driscoll, J. C., & Kraay, A. C. (1998). Consistent covariance matrix estimation with spatially dependent panel data. *Review of economics and statistics*, *80*(4), 549-560.

Duvaleix, S., Emlinger, C., Gaigné, C., & Latouche, K. (2021). Geographical indications and trade: Firm-level evidence from the French cheese industry. *Food Policy*, *102*, 102118.

ESA. (2017). Land Cover CCI Product User Guide Version 2.0. Belgium: UCL Geomatic (Université catholique de Louvain); Friederich-Schille-Universität Jena; Wageningen University; Max-Planckde Louvain; Friederich-Schille-Universität Jena; Wageningen University; Max-Planck-Institut für Meteorologie; JRC European Commission.

Etter, A., McAlpine, C., Wilson, K., Phinn, S., & Possingham, H. (2006). Regional patterns of agricultural land use and deforestation in Colombia. *Agriculture, ecosystems & environment*, *114*(2-4), 369-386.

FAO (2021). Globally Important Agricultural Heritage Systems, Geographical Indications and Slow Food Presidia – Technical note. Food and Agricultural Organization of the United Nations (FAO). Rome.

FAO. (2018). *FRA 2020 Terms and Definitions.* Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2020). *Global Forest Resources Assessment*. Food and Agriculture Organization of the United Nations, Rome, Italy.

FAO. (2022). FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy. Retrieved from: https://www.fao.org/faostat/en/#data [Accessed November 30, 2022].

FNC. (2008). Informacíon economica cafetera. Estadísticas Históricas. Federación Nacional de Cafeteros de Colombia, Bogotá, Colombia.

FNC. (2011). Informacíon economica cafetera. Estadísticas Históricas. Federación Nacional de Cafeteros de Colombia, Bogotá, Colombia.

Freedom House. (2022). Freedom in the World. Retrieved from: https://xmarquez.github.io/democracyData/reference/download_fh.html. [Accessed November 2022].

Galli, F., Prosperi, P., Favilli, E., D'Amico, S., Bartolini, F., & Brunori, G. (2020). How can policy processes remove barriers to sustainable food systems in Europe? Contributing to a policy framework for agri-food transitions. *Food Policy*, *96*, 101871.

Galtier, F.; Belletti, G., and Marescotti, A. (2013) "Geographical Indications for coffee: can they decommodify the market and increase fairness?". Development policy review, 31(5), 597-615.

Geist, H. J., & Lambin, E. F. (2002). Proximate Causes and Underlying Driving Forces of Tropical Deforestation: Tropical forests are disappearing as the result of many pressures, both local and regional, acting in various combinations in different geographical locations. *BioScience*, *52*(2), 143-150.

GFW. (2023). Forest Monitoring Designed for Action. Global Forest Watch. Retrieved from: https://www.globalforestwatch.org/ [Accessed February 1, 2023]

Gibson, L., Lee, T. M., Koh, L. P., Brook, B. W., Gardner, T. A., Barlow, J., ... & Sodhi, N. S. (2011). Primary forests are irreplaceable for sustaining tropical biodiversity. *Nature*, *478*(7369), 378-381.

Giovannucci, D., Josling, T., Kerr, W., O'Connor, B. and Yeung, M.T. (2009). Guide to Geographical Indications: Linking Products and Their Origins; International Trade Centre: Geneva, Switzerland.

Gobbi, J. A. (2000). Is biodiversity-friendly coffee financially viable? An analysis of five different coffee production systems in western El Salvador. *Ecological Economics*, *33*(2), 267-281.

Gocci, A., & Luetge, C. (2020). The synergy of tradition and innovation leading to sustainable geographical indication products: A literature review. *J. Mgmt. & Sustainability*, *10*(1), 152.

Gomez-Peralta, D., Oberbauer, S. F., McClain, M. E., & Philippi, T. E. (2008). Rainfall and cloud-water interception in tropical montane forests in the eastern Andes of Central Peru. *Forest Ecology and Management*, *255*(3-4), 1315-1325.

González-González, A., Villegas, J. C., Clerici, N., & Salazar, J. F. (2021). Spatial-temporal dynamics of deforestation and its drivers indicate need for locally-adapted environmental governance in Colombia. *Ecological Indicators*, *126*, 107695.

Grainger, A. (2008). Difficulties in tracking the long-term global trend in tropical forest area. *Proceedings of the National Academy of Sciences*, *105*(2), 818-823.

Grau, H. R., & Aide, M. (2008). Globalization and land-use transitions in Latin America. *Ecology and society*, *13*(2).

Greenberg, R., Bichier, P., & Sterling, J. (1997). Bird populations in rustic and planted shade coffee plantations of eastern Chiapas, Mexico. *Biotropica*, *29*(4), 501-514.

Haggar, J., Soto, G., Casanoves, F., & de Melo Virginio, E. (2017). Environmental-economic benefits and trade-offs on sustainably certified coffee farms. *Ecological indicators*, *79*, 330-337.

Hansen, M. C., Potapov, P. V., Moore, R., Hancher, M., Turubanova, S. A., Tyukavina, A., ... & Townshend, J. (2013). High-resolution global maps of 21st-century forest cover change. *Science*, *342*(6160), 850-853.

Henry, L. (2022). Adapting the designated area of geographical indications to climate change. *American Journal of Agricultural Economics*.

Hosonuma, N., Herold, M., De Sy, V., De Fries, R. S., Brockhaus, M., Verchot, L., ... & Romijn, E. (2012). An assessment of deforestation and forest degradation drivers in developing countries. *Environmental Research Letters, 7*(4), 044009.

Houghton, R. A., Skole, D. L., Nobre, C. A., Hackler, J. L., Lawrence, K. T., & Chomentowski, W. H. (2000). Annual fluxes of carbon from deforestation and regrowth in the Brazilian Amazon. *Nature*, *403*(6767), 301-304.

Hughes, J. (2009) Coffee and chocolate – Can we help developing country farmers through geographical indications?. A report prepared for the International Intellectual Property Institute, Washington, D.C, US.

Hyde, W. F. (2012). *The global economics of forestry*. Routledge, New York, NY, USA.

Ibanez, M., & Blackman, A. (2016). Is eco-certification a win–win for developing country agriculture? Organic coffee certification in Colombia. *World Development*, *82*, 14-27.

ICO. (2019). *Coffee Development Report 2019: Growing for prosperity Economic viability as the catalyst for a sustainable coffee sector*. International Coffee Organization, London, UK.

ICO. (2021). *The Future of Coffee: Investing in youth for a resilient and sustainable coffee sector*. International Coffee Organization, London, UK.

ICO. (2022). *The Value of Coffee: Sustainability, Inclusiveness, and Resilience of the Coffee Global Value Chain*. International Coffee Organization, London, UK.

Ingram, V., Hansen, M. E., & Bosselmann, A. S. (2020). To label or not? Governing the costs and benefits of geographic indication of an African forest honey value chain. *Frontiers in Forests and Global Change, 3*, 102.

Jezeer, R. E., Santos, M. J., Boot, R. G., Junginger, M., & Verweij, P. A. (2018). Effects of shade and input management on economic performance of small-scale Peruvian coffee systems. *Agricultural systems*, *162*, 179-190.

Jha, S., Bacon, C. M., Philpott, S. M., Rice, R. A., Méndez, V. E., & Läderach, P. (2011). A review of ecosystem services, farmer livelihoods, and value chains in shade coffee agroecosystems. In W. B. Campbell & S. López Ortiz (Eds.), *Integrating Agriculture, Conservation and Ecotourism: Examples from the field*. (pp. 141-208). Springer Science & Business Media.

Josling, T. (2006). The war on terroir: Geographical indications as a transatlantic trade conflict. *Journal of agricultural economics*, *57*(3), 337-363.

Kramer, R. A., Richter, D. D., Pattanayak, S., & Sharma, N. P. (1997). Ecological and economic analysis of watershed protection in Eastern Madagascar. *Journal of Environmental Management*, *49*(3), 277-295.

Lankina, T., Libman, A., & Obydenkova, A. (2016). Authoritarian and democratic diffusion in post-communist regions. *Comparative political studies*, *49*(12), 1599-1629.

Leblois, A., Damette, O., & Wolfersberger, J. (2017). What has driven deforestation in developing countries since the 2000s? Evidence from new remote-sensing data. *World Development*, *92*, 82-102.

Libman, A., & Obydenkova, A. (2013). Communism or communists? Soviet legacies and corruption in transition economies. *Economics letters*, *119*(1), 101-103.

Liu, H., Gong, P., Wang, J., Clinton, N., Bai, Y., & Liang, S. (2020). Annual dynamics of global land cover and its long-term changes from 1982 to 2015. *Earth System Science Data*, *12*(2), 1217-1243.

Liu, J., Liang, M., Li, L., Long, H., & De Jong, W. (2017). Comparative study of the forest transition pathways of nine Asia-Pacific countries. *Forest Policy and Economics*, *76*, 25-34.

Lugo, A. E. (1997). The apparent paradox of reestablishing species richness on degraded lands with tree monocultures. *Forest ecology and management*, *99*(1-2), 9-19.

MacDicken, K. G. (2015). Global forest resources assessment 2015: what, why and how?. *Forest Ecology and Management*, *352*, 3-8.

MADR-UPRA. (2014). Identificacíon General de la Frontera Agrícola en Colombia. Unidad de Planificacíon Rural Agropecuaria. Unidad de Planificación Rural Agropecuaria, Bogotá, Colombia.

Marescotti, A., & Belletti, G. (2016). Differentiation strategies in coffee global value chains through reference to territorial origin in Latin American countries. *Culture & History Digital Journal*, *5*(1), e007-e007.

Mather, A. S. (1992). The forest transition. *Area 23*(4), 367-379.

Matricardi, E. A. T., Skole, D. L., Costa, O. B., Pedlowski, M. A., Samek, J. H., & Miguel, E. P. (2020). Long-term forest degradation surpasses deforestation in the Brazilian Amazon. *Science*, *369*(6509), 1378-1382.

Menapace, L., Colson, G., Grebitus, C., & Facendola, M. (2011). Consumers' preferences for geographical origin labels: evidence from the Canadian olive oil market. *European Review of Agricultural Economics*, *38*(2), 193-212.

Meyer, A. L., Van Kooten, G. C., & Wang, S. (2003). Institutional, social and economic roots of deforestation: a cross-country comparison. *International Forestry Review*, *5*(1), 29-37.

Meyfroidt, P., & Lambin, E. F. (2011). Global forest transition: prospects for an end to deforestation. *Annual review of environment and resources, 36*, 343-371.

Meyfroidt, P., Rudel, T. K., & Lambin, E. F. (2010). Forest transitions, trade, and the global displacement of land use. *Proceedings of the National Academy of Sciences*, *107*(49), 20917-20922.

Mulik, K., & Crespi, J. M. (2011). Geographical indications and the Trade Related Intellectual Property Rights Agreement (TRIPS): A case study of basmati rice exports. *Journal of Agricultural & Food Industrial Organization*, *9*(1).

Murillo-Sandoval, P. J., Van Dexter, K., Van Den Hoek, J., Wrathall, D., & Kennedy, R. (2020). The end of gunpoint conservation: Forest disturbance after the Colombian peace agreement. *Environmental Research Letters*, *15*(3), 034033.

Murtazashvili, I., Murtazashvili, J., & Salahodjaev, R. (2019). Trust and deforestation: A cross-country comparison. *Forest Policy and Economics*, *101*, 111-119.

Myers, N., Mittermeier, R. A., Mittermeier, C. G., Da Fonseca, G. A., & Kent, J. (2000). Biodiversity hotspots for conservation priorities. *Nature*, *403*(6772), 853-858.

Negret, P. J., Sonter, L., Watson, J. E., Possingham, H. P., Jones, K. R., Suarez, C., ... & Maron, M. (2019). Emerging evidence that armed conflict and coca cultivation influence deforestation patterns. *Biological Conservation*, *239*, 108176.

Neilson, J. (2008). Global private regulation and value-chain restructuring in Indonesian smallholder coffee systems. *World Development*, *36*(9), 1607-1622.

Niklitschek, M. E. (2007). Trade liberalization and land use changes: explaining the expansion of afforested land in Chile. *Forest science*, *53*(3), 385-394.

Oberlack, C., Blare, T., Zambrino, L., Bruelisauer, S., Solar, J., Villar, G., ... & Ramírez, M. (2023). With and beyond sustainability certification: Exploring inclusive business and solidarity economy strategies in Peru and Switzerland. *World Development*, *165*, 106187.

Pinoargote, M., Cerda, R., Mercado, L., Aguilar, A., Barrios, M., & Somarriba, E. (2017). Carbon stocks, net cash flow and family benefits from four small coffee plantation types in Nicaragua. *Forests, Trees and Livelihoods*, *26*(3), 183-198.

Puyravaud, J. P. (2003). Standardizing the calculation of the annual rate of deforestation. *Forest ecology and management*, *177*(1-3), 593-596.

Quiñones-Ruiz, X. F., Penker, M., Belletti, G., Marescotti, A., Scaramuzzi, S., Barzini, E., ... & Samper-Gartner, L. F. (2016). Insights into the black box of collective efforts for the registration of Geographical Indications. *Land Use Policy*, *57*, 103-116.

Quiñones-Ruiz, X., Penker, M., Vogl, C., & Samper-Gartner, L. (2015). Can origin labels re-shape relationships along international supply chains?–The case of Café de Colombia. *International Journal of the Commons*, *9*(1).

Rana, P., & Sills, E. O. (2018). Does certification change the trajectory of tree cover in working forests in the tropics? An application of the synthetic control method of impact evaluation. *Forests, 9*(3), 98.

Rice, R. A. (2008). Agricultural intensification within agroforestry: the case of coffee and wood products. *Agriculture, ecosystems & environment*, *128*(4), 212-218.

Rodríguez, N., & Armenteras Pascual, D. (2009). *Monitoreo de los ecosistemas andinos 1985-2005: síntesis*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt.

Rodríguez, N., Armenteras, D., Molowny-Horas, R., & Retana, J. (2012). Patterns and trends of forest loss in the Colombian Guyana. *Biotropica, 44*(1), 123-132.

Rodríguez, N., Armenteras, D., Morales, M., & Romero, M. (2006). *Ecosistemas de los Andes colombianos*. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia.

Rodríguez-de-Francisco, J. C., del Cairo, C., Ortiz-Gallego, D., Velez-Triana, J. S., Vergara-Gutiérrez, T., & Hein, J. (2021). Post-conflict transition and REDD+ in Colombia: Challenges to reducing deforestation in the Amazon. *Forest Policy and Economics*, *127*, 102450.

Ros-Tonen, M.A., & Wiersum, K.F. (2003, May 19–23). *The importance of non-timber forest products for forest-based rural livelihoods: an evolving research agenda* [Conference presentation]. The International Conference on Rural Livelihoods, Forests and Biodiversity, Bonn, Germany.

Rueda, X., & Lambin, E. F. (2013). Responding to globalization: impacts of certification on Colombian small-scale coffee growers. *Ecology and Society*, *18*(3).

Ruf, F., & Schroth, G. (Eds.) (2015). *Economics and ecology of diversification*. The case of tree crops. Springer, London, UK.

Sánchez-Cuervo, A. M., Aide, T. M., Clark, M. L., & Etter, A. (2012). Land cover change in Colombia: surprising forest recovery trends between 2001 and 2010. *PLoS ONE, 7*(8): e43943.

Schwartz, N. B., Aide, T. M., Graesser, J., Grau, H. R., & Uriarte, M. (2020). Reversals of reforestation across Latin America limit climate mitigation potential of tropical forests. *Frontiers in forests and global change*, *3*, 85.

Sills, E. O., Herrera, D., Kirkpatrick, A. J., Brandão Jr, A., Dickson, R., Hall, S., ... & Pfaff, A. (2015). Estimating the impacts of local policy innovation: the synthetic control method applied to tropical deforestation. *PloS one, 10*(7), e0132590.

Sohngen, B. (2020). Forest management and trade for forest products. In: A., Blackman (Ed.), *Latin American and Caribbean forests in the 2020s: Trends, challenges, and opportunities.* (pp. 124-158). IDB, Washington, DC.

Somarriba, E., & López Sampson, A. (2018). Coffee and cocoa agroforestry systems: pathways to deforestation, reforestation, and tree cover change. Background paper for Leveraging Agricultural Value Chains to Enhance Tropical Tree Cover and Slow Deforestation (LEAVES).

Sulla-Menashe, D., Gray, J. M., Abercrombie, S. P., & Friedl, M. A. (2019). Hierarchical mapping of annual global land cover 2001 to present: The MODIS Collection 6 Land Cover product. *Remote Sensing of Environment*, *222*, 183-194.

Takahashi, R., & Todo, Y. (2013). The impact of a shade coffee certification program on forest conservation: A case study from a wild coffee forest in Ethiopia. *Journal of Environmental Management*, *130*, 48-54.

Takayama, T., Norito, T., Nakatani, T., & Ito, R. (2021). Do geographical indications preserve farming in rural areas? Evidence from a natural experiment in Japan. *Food Policy*, *102*, 102101.

Teuber, R. (2010). Geographical indications of origin as a tool of product differentiation: The case of coffee. *Journal of International Food & Agribusiness Marketing*, *22*(3-4), 277-298.

UN. (2014). System of Environmental-Economic Accounting 2012, Central Framework. United Nations, New York, NY, USA.

UNCTAD (2019). International classification of non-tariff measure. United Nations Publications, New York, USA

Vandecandelaere, E., Teyssier, C., Barjolle, D., Fournier, S., Beucherie, O., & Jeanneaux, P. (2020). Strengthening sustainable food systems through geographical indicationsAn Analysis of Economic Impacts, 2018, Food and Agriculture Organization of the United Nations, Rome, Italy.

Vanderhaegen, K., Akoyi, K. T., Dekoninck, W., Jocqué, R., Muys, B., Verbist, B., & Maertens, M. (2018). Do private coffee standards 'walk the talk'in improving socio-economic and environmental sustainability?. *Global Environmental Change*, *51*, 1-9.

Vaquero-Piñeiro, C. (2021). The long-term fortunes of territories as a route for agri-food policies: evidence from Geographical Indications. *Bio-based and Applied Economics*, *10*(2), 89.

WB. (2022). World Development Indicators. World Bank, Washington, D.C., US. Retrieved from: http://data.worldbank.org/data-catalog/world-development-indicators [Accessed November 2022].

Wiśniewski, P., & Märker, M. (2019). The role of soil-protecting forests in reducing soil erosion in young glacial landscapes of Northern-Central Poland. *Geoderma*, *337*, 1227-1235.

Appendix

Table A 1. Variables' definitions.

Variable name	Definition	Source
Agricultural area – *AGR*	Share of agricultural (farming and livestock) area over total land area.	FAOSTAT (FAO, 2022).
Population density – *POP*	Total population over land area.	FAOSTAT (FAO, 2022).
People leaving in rural areas – *POP_RUR*	Share of rural people over total population.	FAOSTAT (FAO, 2022).
Trade openness – *TRD_OP*	Sum of import and export as share of total GDP.	WDI (WB, 2022).
Cereal yield – *CER_Y*	Kilograms per hectare of harvested land.	FAOSTAT (FAO, 2022).
Temperature change – *TEMP*	Mean monthly temperature anomalies with respect of a baseline climatology corresponding to the period 1951-1980.	FAOSTAT (FAO, 2022).
GDP per capita – *GDP_CAP*	Gross domestic product per capita at 2015 constant US$.	WDI (WB, 2022).
House of freedom index – *INS*	Sum of the two variables of civil liberties and political rights rescaled from 1 to 10 (where 1 is the lowest institutional quality level and 10 the highest).	FAOSTAT (FAO, 2022).
Agricultural trade openness – *AGR_OP*	Ratio between the value of agricultural exports and imports.	Authors' elaboration of FAOSTAT (FAO, 2022) data.
Coffee production – *COF*	Coffee production as share of total crop production.	Authors' elaboration of FAOSTAT (FAO, 2022) data.
Deforestation – *DEF*	Deforestation rate, calculated on total forest (natural and planted forest) for the reconstructed data and on the sum of tree and mangroves cover for CCI-LC data.	Author's personal reconstruction; FAOSTAT (FAO, 2022).

Table A 2. Forest predictors' means, Colombia *vs* donor pool.

	Agricultural area	**Population density**	**People leaving in rural areas**	**Trade openness**	**Cereal yield**	**Temperature change**	**GDP per capita**	**House of freedom index**	**Agricultural trade openess**
Argentina	0,45	0,14	0,1	28,67	3873,65	0,47	11722,31	7,99	13,82
Bolivia	0,34	0,09	0,35	58,42	1682	0,6	2115,75	7,1	1,94
Brazil	0,28	0,22	0,17	21,41	2829,03	0,95	7109,65	7,56	6,06
Chile	0,21	0,22	0,13	60,55	4586,62	0,35	7806,03	9,34	2,13
Colombia	**0,4**	**0,38**	**0,24**	**33,48**	**2950,3**	**0,6**	**3974,18**	**5,86**	**1,85**
Costa Rica	0,36	0,85	0,33	79,48	3144,67	0,37	7101,63	9,68	3,17

Cuba	0.61	1.05	0.24	49.69	2472.74	0.80	4552.82	0.37	0.77
Ecuador	0,28	0,56	0,38	42,15	1918,29	0,66	4322,66	6,81	3,21
El Salvador	0.62	2.90	0.37	58.44	1879.78	0.80	2748.35	7.29	0.73
Guatemala	0,4	1,25	0,53	43,41	1721,85	0,79	2956,13	5,26	2,12
Guyana	0,06	0,04	0,72	166,51	3154,61	0,88	3114,65	7,79	2,13
Honduras	0,3	0,69	0,49	76,08	1279,29	0,76	1678,16	6,03	1,6
Jamaica	0.43	2.46	0.48	91.11	1515.45	0.81	4478.37	7.70	0.53
Mexico	0,53	0,55	0,24	27,68	2128,62	0,77	6992,36	6,87	0,87
Nicaragua	0,41	0,46	0,43	59,03	1424,42	0,71	1898,17	5,52	1,62
Paraguay	0,39	0,14	0,45	51,09	1532,24	0,52	2951,95	6,41	3,93
Peru	0,19	0,22	0,25	34,63	2034,98	0,8	3424,98	6,49	0,87
Uruguay	0,84	0,19	0,07	34,52	1426,39	0,64	7237,17	9,68	3,83
Venezuela	0,24	0,3	0,13	49,64	1658,7	0,66	12971,21	4,6	0,11

Notes: variables are averaged on the pre-treatment period, from 1992 to 2020.

Table A 3. Pre-treatment Forest predictors mean: Colombia, synthetic Colombia and donor pool.

	Colombia		**Donor pool**
	Real	*Synthetic*	
AGR	0.396	0.354	0.386
POP	0.344	0.395	0.686
POP_RUR	0.276	0.281	0.326
TRD_OP	30.904	43.199	57.417
CER_Y	2539.257	2506.81	2242.21
TEMP	0.409	0.418	0.692
GDP_CAP	3535.416	4945.59	5196.75
INS	5.476	7.290	6.805
AGR_OP	2.356	2.322	2.747
t-1 deforestation	0.003	0.003	0.002
t-2 deforestation	0.003	0.003	0.002
t-3 deforestation	0.003	0.003	0.002

Notes: variables are averaged from 1992 to 2020 (pre-treatment period); the t-1 level of deforestation (lagged variable of the outcome) is averaged from 1993 to 2020, the t-2 level of deforestation from 1994 to 2020, while the t-3 level of deforestation share from 1995 to 2020.

Table A 4. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia.

Country	Synthetic Colombia weight
Argentina	0.092
Bolivia	0.35
Brazil	0
Chile	0.109
Costa Rica	0.08
Cuba	0.004
Ecuador	0.022

El Salvador	0.012
Guatemala	0.009
Guyana	0.003
Honduras	0.007
Jamaica	0.021
Mexico	0.271
Nicaragua	0.015
Perù	0.013
Paraguay	0.025
Uruguay	0.003
Venezuela	0.036

Notes: Countries with positive weights are used as donors.

Table A 5. Weights donated by each country of the donor pool, coffee production.

Country	**Synthetic Colombia weight**
Argentina	-
Bolivia	0
Brazil	0
Chile	-
Costa Rica	0.735
Cuba	0.146
Ecuador	0
El Salvador	0
Guatemala	0
Guyana	0
Honduras	0
Jamaica	0
Mexico	0.005
Nicaragua	0
Perù	0.086
Paraguay	0.028
Uruguay	-
Venezuela	0

Notes: Countries with positive weights are used as donors.

Table A 6. Weights donated by each country of the donor pool, 2007 EU registration.

Country	**Synthetic Colombia weight**
Argentina	0.050
Bolivia	0.292
Brazil	0.082
Chile	0.04
Costa Rica	0
Cuba	0
Ecuador	0
El Salvador	0.032
Guatemala	0
Guyana	0
Honduras	0
Jamaica	0
Mexico	0.274
Nicaragua	0
Perù	0.230
Paraguay	0

Uruguay	0
Venezuela	0

Notes: Countries with positive weights are used as donors.

Figure A 1. Deforestation trend, Colombia vs synthetic Colombia – excluding Brazil.

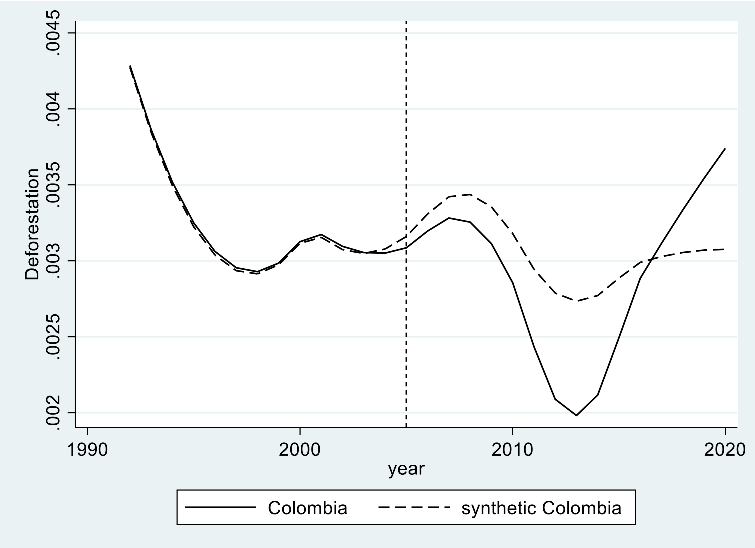


Table A 7. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – excluding Brazil.

Country	Synthetic Colombia weight
Argentina	0.076
Bolivia	0.452
Brazil	-
Chile	0.145
Costa Rica	0.001
Cuba	0.004
Ecuador	0.001
El Salvador	0.044
Guatemala	0.004
Guyana	0.001
Honduras	0.003
Jamaica	0.003
Mexico	0.196
Nicaragua	0
Perù	0.011
Paraguay	0.59
Uruguay	0.002
Venezuela	0

Notes: Countries with positive weights are used as donors.

Figure A 2. Deforestation trend, Colombia vs synthetic Colombia – all countries.

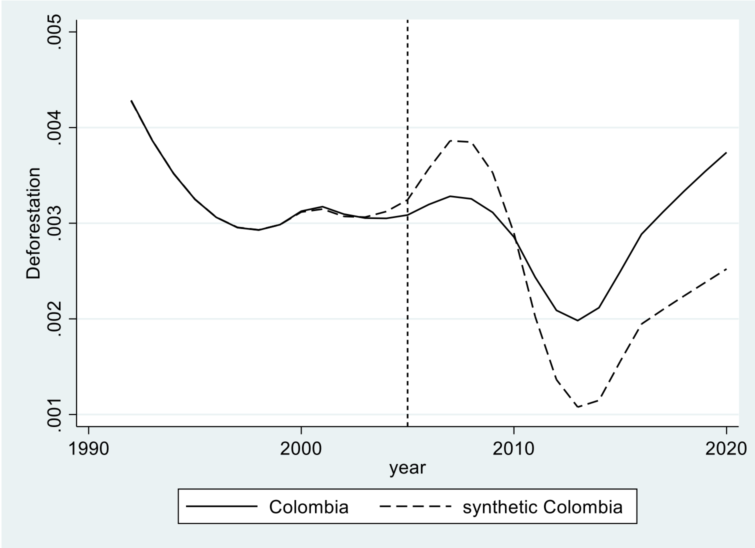


Table A 8. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – all countries.

Country	Synthetic Colombia weight
Argentina	0.036
Belize	0
Bolivia	0.290
Brazil	0
Chile	0.34
Costa Rica	0
Cuba	0
Dominican Republic	0
Ecuador	0
El Salvador	0.029
Guatemala	0.091
Guyana	0
Honduras	0
Jamaica	0
Mexico	0.090
Nicaragua	0.037
Panama	0
Paraguay	0.086
Perù	0
Uruguay	0
Venezuela	0

Notes: Countries with positive weights are used as donors. Barbados, French Guiana and Suriname have been discarded from the donor pool as data on deforestation are not available for the entire period.

Figure A 3. Deforestation trend, Colombia *vs* synthetic Colombia – excluding countries with no data for coffee.

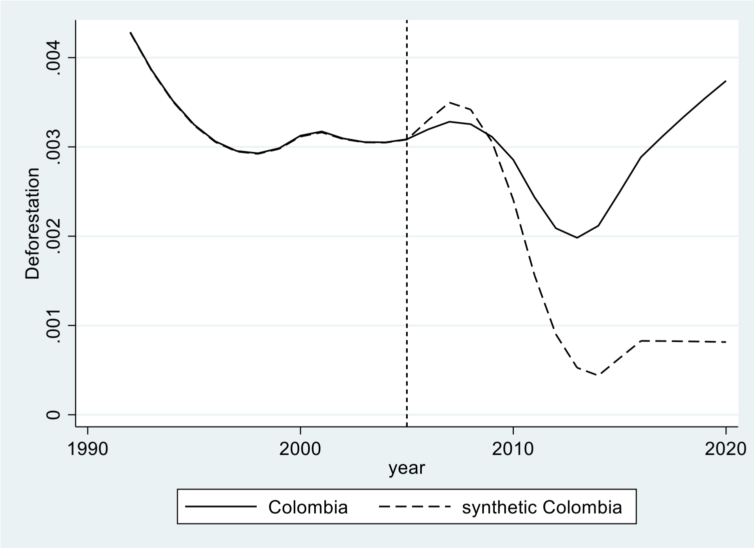


Table A 9. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – excluding countries with no data for coffee.

Country	Synthetic Colombia weight
Argentina	-
Bolivia	0.003
Brazil	0.268
Chile	-
Costa Rica	0.232
Cuba	0.002
Ecuador	0.003
El Salvador	0.002
Guatemala	0.024
Guyana	0
Honduras	0.001
Jamaica	0
Mexico	0.091
Nicaragua	0.003
Perù	0.356
Paraguay	0.002
Uruguay	-
Venezuela	0.013

Notes: Countries with positive weights are used as donors. Argentina, Chile, Uruguay and French Guiana have been discarded from the donor pool as data on coffee production are not available for the entire period.

Figure A 4. Deforestation trend, Colombia *vs* synthetic Colombia – 1982-2020.

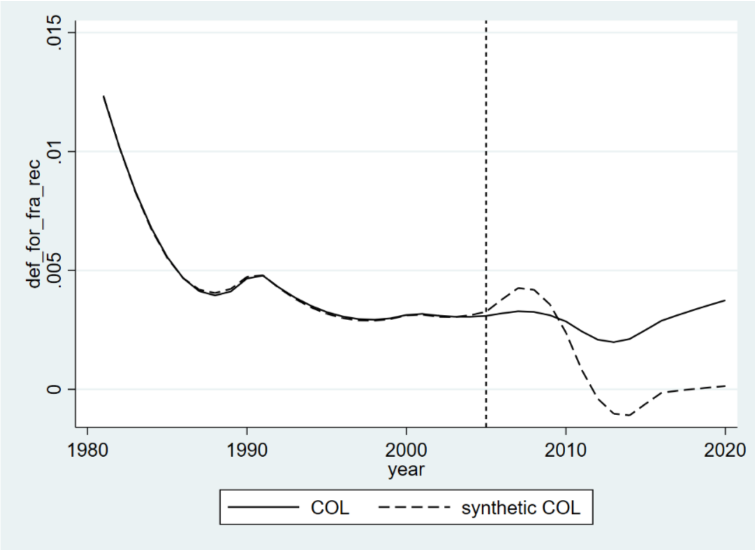


Table A 10. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – 1982-2020.

Country	Synthetic Colombia weight
Argentina	0.089
Bolivia	0.126
Brazil	0.001
Chile	0.434
Costa Rica	0
Cuba	0.006
Ecuador	0
El Salvador	0.01
Guatemala	0.254
Guyana	0
Honduras	0
Jamaica	0
Mexico	0.007
Nicaragua	0.041
Perù	0.001
Paraguay	0.026
Uruguay	0.003
Venezuela	0

Notes: Countries with positive weights are used as donors.

Figure A 5. Deforestation trend, Colombia *vs* synthetic Colombia – FOR_CCI data.

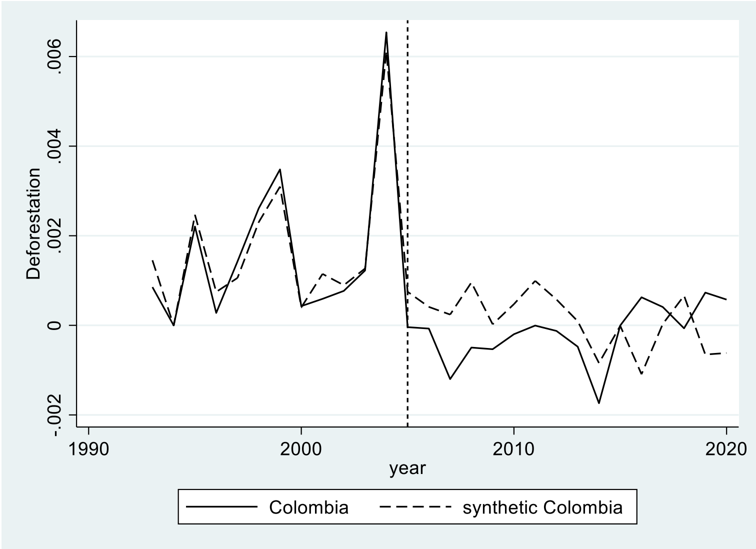


Table A 11. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – FOR_CCI data.

Country	Synthetic Colombia weight
Argentina	0.073
Bolivia	0.011
Brazil	0.049
Chile	0.001
Costa Rica	0.004
Cuba	0.132
Ecuador	0.094
El Salvador	0.011
Guatemala	0.011
Guyana	0.002
Honduras	0.007
Jamaica	0.002
Mexico	0.067
Nicaragua	0.005
Paraguay	0.011
Perù	0.511
Uruguay	0.009
Venezuela	0

Figure A 6. Deforestation trend, Colombia *vs* synthetic Colombia – FOR_FRA data.

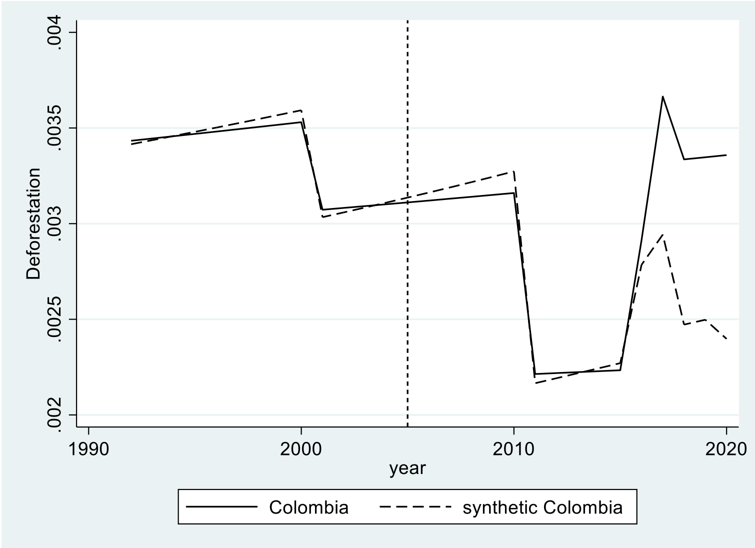


Table A 12. Weights donated by each country of the donor pool, Colombia *vs* synthetic Colombia – – FOR_FRA data.

Country	Synthetic Colombia weight
Argentina	0.019
Bolivia	0.249
Brazil	0.147
Chile	0.084
Costa Rica	0.001
Ecuador	0.004
El Salvador	0.038
Guatemala	0.002
Guyana	0
Honduras	0.001
Jamaica	0
Mexico	0.233
Nicaragua	0.005
Paraguay	0.011
Perù	0.197
Uruguay	0
Venezuela	0.006

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