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Abstract

This study analyzes the expected effects of climate change on Colombia's current account. To this end, we present a literature review that outlines how climate-related risks could impact the balance of payments, complemented with an analysis that illustrates how the 2014-2015 oil shock affected the country's external sector. Subsequently, we show a projection of the current account balance through 2050 under different climate scenarios in order to establish whether the incidence of these risks would affect the country's long-run current account. Our results indicate that achieving net-zero emissions by 2050 could widen the current account deficit, relative to a continuation of current climate policies, by an amount ranging between 2.6% and 4.6% of GDP.

JEL codes: F32, G18, Q51, Q54

Keywords: climate change, current account, climate-related risks, fully modified OLS.

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Los efectos esperados del cambio climático sobre la cuenta corriente en Colombia

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Resumen

Este estudio muestra los efectos esperados del cambio climático sobre la cuenta corriente en Colombia. Para ello presentamos una revisión de literatura que expone cómo los riesgos asociados con este fenómeno podrían impactar la balanza de pagos, complementando con un análisis que ilustra cómo el choque petrolero de 2014-2015 afectó el sector externo del país. Posteriormente, realizamos una proyección del balance corriente hasta 2050 bajo distintos escenarios climáticos con el objetivo de establecer si la incidencia de estos riesgos afectaría el balance corriente en el largo plazo. Nuestros resultados indican que la consecución de cero emisiones netas podría ampliar el déficit corriente hacia 2050, relativo a una continuidad de las políticas climáticas actuales, en una cantidad que oscilaría entre 2,6% y 4,6% del PIB.

Códigos JEL: F32, G18, Q51, Q54

Palabras clave: cambio climático, cuenta corriente, riesgos asociados al cambio climático, mínimos cuadrados totalmente modificados.

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1. Introduction

During the past decades, the global temperature has increased dramatically (1.1°C) with respect to pre-industrial levels, a trend expected to continue throughout the 21st century and which will be determined by the emission of greenhouse gases, the main cause of climate change (Bárcena *et al*., 2020). Under the most encouraging scenario, which involves meaningful efforts undertaken to curb CO2 emissions, average temperatures are expected to increase by 2°C; between 3.5°C and 4°C if current climate policies are maintained (IPCC, 2021; Acevedo *et al.*, 2017). Therefore, regardless of future climate states, impacts arising from this phenomenon will worsen, expressed in a greater frequency, intensity, and duration of climate-related disasters such as hurricanes, droughts, and floods, among others (NGFS, 2020; Knuston *et al*., 2010).

This is alarming since the costs associated with these types of crashes are considerable. Although there is high uncertainty and heterogeneity in the results reported by the literature related to the subject, on average it has been found that an increase of 2.5°C in global temperature generates a loss equivalent to 1.4% of GDP and, depending on the pace of the implementation of measures to mitigate the effects of climate change, this loss could reach 4 percentage points (p.p.) (Tol, 2018).

Although this impact could initially be considered as moderate, its increases in tandem with temperature, with a cost of 2% of GDP in the event of an increase of 3°C, reaching 8.1% in the event of an increase of 6°C (Nordhaus and Moffat, 2017)[1]. Additionally, the effects on the economy are persistent. According to Dell *et al*. (2012), a 1°C increase in temperature would reduce the long-term economic growth rate by 1.6 percentage points.

Therefore, to minimize the macroeconomic impacts of climate change, several initiatives have been established globally –1,302 between 1998 and 2017– to contain this phenomenon, most of them aimed at limiting the consumption and production of fossil fuels, the main source of greenhouse gases (Gaulin and Le Billon, 2020; Barrett *et al*., 2020; IEA, 2019; Krogstrup and Oman, 2019; World Bank, 2019; Batten, 2018)[2]. Such measures, although favorable for the environment and effective to avoid the costs associated with natural disasters, imply notorious risks for economies whose incomes rely on the commercialization of mining products. The transition to a low-carbon economy implies the adoption of new energy sources and market schemes, which will necessarily cause a change in

[1] Tol (2018) and Nordhaus and Moffat (2017) perform a meta-analysis on the subject using samples composed of 22 and 27 studies, respectively.
[2] McGlade and Ekins (2015) calculate that to limit the increase in temperature by 2050 to 2°C, one-third of oil reserves are required; half of the gas reserves; and 80% of the coal reserves are not extracted and exploited commercially until then.

the demand for this type of product and, therefore, a notable contraction in the foreign income of these countries. (Bernal and Ocampo, 2020).

In Colombia, where exports of mining products contributed 37% of the external current income and this sector represented 42% of direct foreign investment between 2000 and 2020, an eventual weakening in the global demand for fossil fuels could lead to a negative dynamic in the balance of payments, whose behavior is widely influenced by oil price shocks (Toro *et al*., 2015). In the absence of economic alternatives to compensate for the expected decrease in this source of income, there would be a widening of the current account deficit and increases in external financing costs, aspects that would be reflecting a deterioration in the country's external position due to the implementation of policies built to curb climate change at a global level.

Addressing this concern, in this study we built an econometric analysis that shows how, under scenarios with faster implementation of climate change mitigating policies, the current account deficit in Colombia would be greater by an amount that ranges between 2.6% and 4.6% of GDP compared to scenarios that keep current climate policies. This deterioration would be lessened by a permanent drop in oil prices and a substantial increase in the public debt, shocks which are attributable to the weakening of the global demand for fossil fuels and the increase in public spending to meet environmental goals in scenarios with lower incidence of climate change.

The rest of this study is organized as follows: the second section describes the risks associated with climate change and the scenarios we consider in this study. The third section contains a literature review that exposes how these risks can affect the balance of payments of countries with high vulnerability to them. The fourth section presents the variables, sources of information and the econometric approach used to project the current account balance. The fifth section shows the projection of the current account balance between 2021 and 2050 under different climate scenarios and the analysis of the effects of the risks associated with climate change on Colombia's long-term external position. The sixth section concludes.

2. Risks and scenarios associated with climate change

To analyze how the incidence of risks associated with climate change can affect Colombia's long-term current account, we use the climate scenarios constructed by the NGFS (Network for Greening the Financial System). These scenarios constitute an analytical framework that allows the identification of macroeconomic and financial risks during the next decades under assumptions that differ in the scope of climate policies and technological advances to remove carbon from the atmosphere. Considering the high degree of uncertainty that inherently arises in this type of analysis, three socioeconomic models are used to generate possible trajectories of the variables of interest (NGFS, 2021)[3].

The risks considered in the NGFS climate scenario analysis are physical and transition risks. The former captures the impacts generated by shocks and climatic changes (e.g. hurricanes, floods, droughts, among others) that cause economic losses that can amount to 25% of GDP. The latter comprises costs resulting from economic transformations caused by changes in environmental policy and regulation, technological advances, and changes in consumer preferences, which can reach 9% of GDP (NGFS, 2020).

It is expected that the implementation of robust climate policies will reduce the incidence of physical risks since the implementation of mitigation measures will limit the economic losses. However, the achievement of the environmental goals pursued by these measures generally implies using mechanisms (taxes, negotiable permits, subsidies) that affect the return of certain economic sectors and increase the financing needs, boosting the transition risks.

These trade-offs arise in the different NGFS climate scenarios we consider in this study (current policies, delayed transition, and net-zero emissions to 2050). The current policies scenario assumes that existing climate policies are remained over the following decades, without further efforts to strengthen actions to mitigate climate change. Under this scenario, the global temperature would exceed 3°C –relative to pre-industrial levels– by the year 2080, which would imply a high incidence of physical risks. Likewise, technological advances in this area would be gradual, limiting the capacity to remove carbon and, therefore, contain environmental impacts.

Unlike the current policies scenario, the delayed transition and net-zero emissions scenarios consider climate goals to contain climate change. The first assumes that the global temperature will remain below 2°C –relative to pre-industrial levels– in 2100; the second imposes the achievement of zero net emissions in 2050 and sets the limit for the increase in temperature at 1.5°C for the same time

[3] The NGFS scenarios are supported by three models, which vary in geographic attributes and economic sectors: GCAM, MESSAGEix-GLOBIOM, and REMIND-MAgPIE. The paths for the macroeconomic variables are generated by combining information from these with a global macroeconomic model (NiGEM) that incorporates trade between countries and integrates capital markets. The MESSAGEix-GLOBIOM and REMIND-MAgPIE models favor macroeconomic analysis because they allow endogenous changes in macroeconomic variables (e.g. prices, consumption, GDP, among others). However, only the results associated with the REMIND-MAgPIE model are presented, since it allows modelling endogenous technological changes and has a higher frequency in the data (Bertram *et al*., 2020).

horizon[4]. The main mechanism used to achieve climate goals consists of policies' implementation (e.g. environmental taxes or tradable permit systems) that internalize the social cost associated with carbon emissions to the agents that produce them. These policies increase the final price of energy, reducing final energy consumption[5]. The contraction in demand leads to a decrease in the price of fossil fuels, deteriorating the terms of trade between countries that export this type of goods (NGFS, 2020).

The main difference between the scenarios lies in the pace of the implementation of the measures that will allow for meeting the emissions goal. The 2050 net-zero emissions scenario assumes the immediate introduction of climate policies that increase the final price of carbon, facilitating an accelerated transition to renewable energy sources. For its part, the delayed transition scenario maintains current climate policies until 2030, followed by the implementation of stricter measures to reach the 2°C goal by 2050[6].

Another explanatory aspect of the divergences in the trajectories generated in each scenario lies in the availability of technologies that allow the removal of carbon from the atmosphere. For example, the 2050 net-zero emissions scenario contemplates a greater capacity to remove carbon due to the timely introduction of mitigation policies, which favors an orderly and gradual cut in the use of fossil fuels, in addition to the imposition of climate measures comparatively mild[7]. Therefore, under this scenario, the final price of energy decreases at a lower rate and magnitude in the long term, limiting the expected deterioration in the terms of trade between countries that export fossil fuels.

Finally, public debt is determined by the following factors: economic losses generated by climatic shocks and natural disasters, which affect economic activity in the different productive sectors; costs of emergency care and reconstruction of the affected infrastructure; expenses associated with the implementation of climate policies derived from multilateral agreements (Bernal *et al*., 2022). These

[4] Net zero emissions consists of a situation where positive carbon emissions offset the anticipated fulfillment of climate goals in countries that adopt a strict policy in this area, mainly the United States, the European Union and China (NGFS, 2021).
[5] To reach a net zero emissions scenario, the carbon price would have to be close to 160 dollars per ton by 2050, which would increase the final oil price by this amount (NGFS, 2021).
[6] Graph A.1 shows the carbon price paths for the different climate scenarios between 2021 and 2050.
[7] In the current policy scenario, coal and oil maintain their share of 25% and 30%, respectively, in energy sources. In the delayed transition, the participation of these energy sources is maintained until 2030; by 2050, coal consumption will have an almost zero share and oil less than a quarter, while there is a considerable increase in the use of renewable energies, going from a contribution of less than 25% in 2020 and 2030 to almost 70% in 2050. The 2050 zero emissions scenario assumes a more orderly and gradual change, reducing the share of carbon from approximately 30% in 2020 to 13% in 2030 and almost zero in 2050; and the share of oil goes from 30% in 2020 to 23% in 2050, with growth in the use of renewable energies reaching almost 50% share in 2050 (NGFS, 2020).

factors vary between scenarios and in their effects on the Central Government's indebtedness. For example, under the zero net emissions scenario, countries assume commitments to mitigate climate change, so that public spending in this area exceeds that of other scenarios. Likewise, the contraction of the global demand for mining-energy products cuts oil rents and, therefore, the income of the Government. However, in this case, economic growth is greater, since a lower incidence of weather shocks minimizes sectoral economic losses, while costs related to the reconstruction of the affected infrastructure are avoided. On the opposite, under a scenario that maintains current climate policies, public spending would be lower since there would be no strengthening of policies. Additionally, oil revenues would be higher since the global demand for mining-energy products remains robust. However, in this case, a reduction in economic growth is anticipated because of sectoral losses generated by natural disasters, as well as increases in public spending for reconstruction and adaptation to climate change.

3. The effects of climate shocks on the balance of payments: a literature review

According to the literature, among the main physical and transition risks that can impact the balance of payments, the following stand out: i) the deterioration of transport infrastructure and higher logistics costs; ii) negative shocks to agricultural productivity; iii) drop in the prices of mining-energy products; iv) increase in the cost of external borrowing. The first two represent physical risks, while the two last ones are transition risks.

The expected increase in the frequency and intensity of meteorological shocks (e.g. landslides and rises in sea level) would negatively affect the productivity of critical transport infrastructure to support international trade, such as ports and highways (IPCC, 2014; Schweikert *et al*., 2014; WTO, 2009). DNP-IDB (2014) estimates that, by 2040, the effects of climate change will reduce the operating capacity of the transport sector in Colombia by 2.3% each year. Aggravating logistical deficiencies that affect the country's competitiveness in international markets and notably limit commercial activity (Ramírez *et al*., 2021; García *et al*., 2019; Arvis *et al*., 2016; Dennis and Shepherd, 2011).

The increase in the incidence of climatic shocks –e.g. floods and droughts – will cause, as in the transport sector, economic losses that will negatively affect agricultural productivity. According to Zhai and Zhuang (2009), by 2080 world production will decrease 7.4% because of the effects of climate change, impacting developing countries to a greater extent[8]. Gallic and Vermandel (2020)

[8] This reduction would amount to 20% between low- and middle-income countries (Masters *et al*., 2010).

estimate that climate fluctuations explain 35% of the variation in New Zealand's agricultural output. Along the same lines, Álvarez-Espinosa *et al*. (2014) estimate that in Colombia the total annual production of this sector would fall between 1.9% and 2.8%, which in turn would cut (increase) sectoral exports (imports) by approximately 6.3% (2, 2%) each year.

There is an expected drop in the price of mining-energy products due to the establishment of policies and regulations aimed at curbing the effects of climate change, particularly those that promote the transition to renewable energy sources. These policies would gradually contract the global demand for fossil fuels, considerably reducing external income among economies with a high dependence on exports of this type of goods (Bernal and Ocampo, 2020; NGFS, 2019; Carbone and Rivers, 2017; Sorin and Pilasluck, 2015; Boehringer *et al*., 2010).

Mattoo *et al*. (2012) estimate that in the face of a 17% contraction in global carbon emissions by 2020 relative to 2005 levels the value of energy exports in low- and middle-income countries would experience a reduction of 8.2% in relation to a scenario that maintains the current policies. In South Africa, the value of coal exports would decrease by 65% by 2035 in response to a 50% contraction in external demand for this product, a cost equivalent to a third of GDP (Huxham *et al*., 2019). Makarov *et al*. (2020) project that, if the goals associated with the Paris Agreement by 2030 (UNFCCC, 2015), are achieved, the decline in the value of Russian fossil fuel exports would cut its economic growth rate by half a percentage point. In the case of Colombia, the transition to renewable energy sources would reduce coal demand by 68% by 2030, limiting the volume of exports (Oei and Mendelevitch, 2019).

The expected drop in both economic growth and the capacity to create current income would increase external borrowing costs. Uncertainty related to the future external earnings would deteriorate investor confidence, causing a decrease in net capital inflows to emerging markets (Bems *et al*., 2016; Erduman and Kaya, 2016; Sarno *et al*., 2016; Adler *et al*., 2016; Ahmed and Zlate 2014). Regarding this risk, the literature finds that countries with a high degree of climate vulnerability would have to assume borrowing costs that would be, on average, 1.2% higher (Kling *et al*., 2018)[9]. This increase could be explained by a higher interest rate associated with public debt securities and the sovereign risk premium (Cevik and Jalles, 2020). In some cases, the intensity of climatic shocks, particularly in agricultural or tropical countries, can cause a decrease in the ability to pay sovereign debt (IMF, 1999; Vos *et al*., 2000; Sturzenegger and Zettelmeyer, 2007; Malucci, 2020).

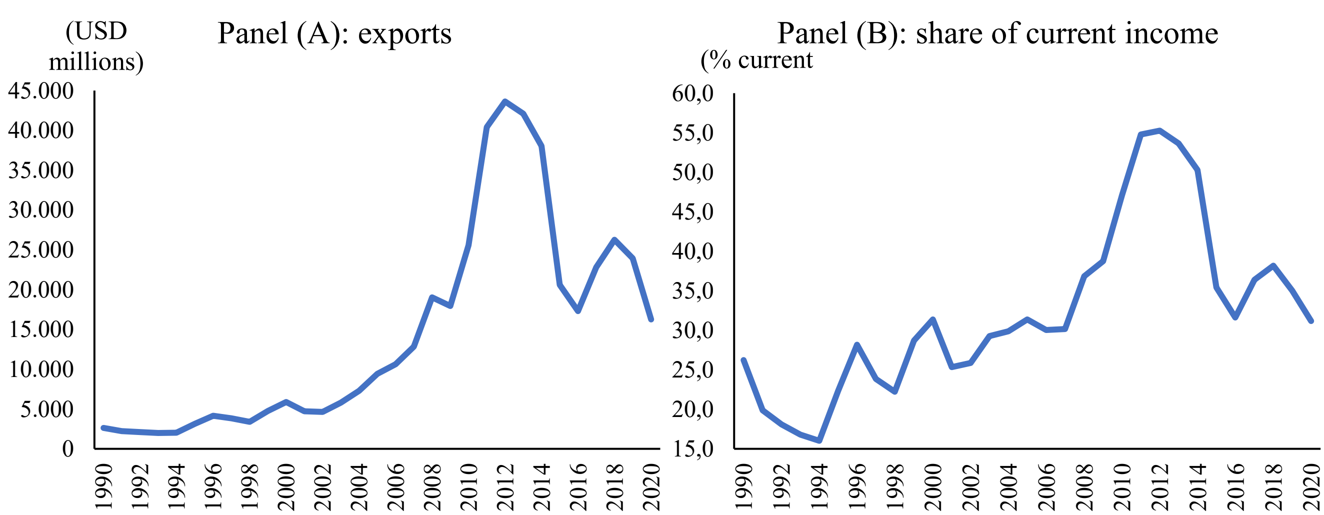
[9] Kling *et al*. (2018) measure the climatic vulnerability of a country through an index that weighs the annual human and economic losses associated with climatic disasters between 1997-2016.

As a result, a deterioration in the terms of trade could occur in the future, reflected in a real depreciation and increment in the sovereign risk premium (Arndt *et al*., 2019; Bauer *et al*., 2016; Hamann *et al*., 2015; Carney, 2015; González *et al*., 2015). The depreciation would arise from a contraction in domestic demand for non-tradable goods —resulting from the fall in current income—, an aspect that would lead to a sectoral reallocation of excess productive capacity towards the tradable sector (Kapfhammer *et al*., 2020; Jakob and Steckel, 2014; Amano and van Norden, 1995). Likewise, a decrease in foreign direct investment would be expected, which would considerably reduce the supply of foreign exchange in economies where oil revenues contribute to a substantial proportion of the current income (López *et al*., 2013). On the other hand, the increase in the sovereign risk premium would derive from the uncertainty related to the future capacity to generate income, deteriorating investor confidence.

3.1. Effects of the 2014-2015 oil shock on the external sector in Colombia

During the last decades, the episodes characterized by favorable terms of trade, mainly due to increases in the price of oil, generated surpluses that made it possible to cushion current deficits in other sectors related to expansions in domestic demand and the payment of rents to foreign companies. (Toro *et al*., 2015; López *et al*., 2013). However, this deepened the economic dependence on oil revenues, which increased the country's vulnerability to external shocks that may limit economic growth (Garavito *et al*., 2020).

Graph 1. Exports of mining goods in Colombia (1990-2020)



Source: Banco de la República.

On average, between 2000 and 2020, exports of mining-energy products reached a value equivalent to 6% of GDP, contributing 37% of current income – more than 50% during the boom in oil prices at the beginning of the previous decade – and 42% of foreign direct investment (FDI). Consequently, it is foreseen that a negative shock to oil prices, as might be expected under some climate scenarios, would generate significant external imbalances in the Colombian economy. According to Álvarez-Espinosa *et al*. (2014), between 2011 and 2100, Colombian exports would have an annual decrease of 0.27% in their total value due to the risks associated with climate change (RACC). For their part, Álvarez-Espinoza *et al*. (2017) calculate that the implementation of mitigation measures that allow the country to comply with the national commitments proposed in COP21 —reducing emissions by 20% related to a scenario without climate policies (i.e. business as usual)— would cut the value of exports between 8% and 9% in 2040. According to Toro *et al*. (2015), the oil shock of 2014-2015 generated a widening of the current deficit that reached 7% of GDP, an effect mediated by an annual fall in the terms of trade of 28.5% and a real depreciation of 42%. For the same period and applying a 10% negative price shock, Melo *et al*. (2016) reported a devaluation of 8.1% in the real exchange rate. Along similar lines, Francis and Restrepo-Ángel (2018) showed that a positive shock in the oil price appreciates the Colombian peso and that the opposite could be expected in the face of a negative impulse.

The change in the country's capital flows during the 2014 oil shock also fits the effects reported in the literature. Toro *et al*. (2015) indicate that between 2014 and 2015, FDI flows in the oil sector decreased by 35%, and the EMBI sovereign risk premium index for Colombia increased by 121 p.b. The authors attribute the deterioration in risk perception to uncertainty about the economy's capacity to generate future income and its implications for the fiscal situation. Similarly, Melo *et al*. (2016) show that the 2014 oil shock increased public debt, an aspect that reinforces this point since the country's fiscal situation worsened. Although they do not find a statistically significant effect on FDI flows, Francis and Restrepo-Ángel (2018) report an increase in the EMBI for Colombia.

4. Estimation of the current account balance

In this section, we present a projection of Colombia's current balance under different climate scenarios in order to establish whether the incidence of risks associated with climate change would affect the country's current account in the long term. Initially, we estimate the current balance between 1997 and 2020 to obtain its long-term relationship with some of its main determinants. Then, we conduct a linear projection of the current balance between 2021 and 2050 using the estimation results and the trajectories forecasted for the determinants – coming from various exogenous sources. Finally, we measure the deviations of the current balance with respect to a scenario in which current policies remain to analyze how policies implementation to mitigate climate change could affect the country's long-term current account deficit.

It is worth clarifying that several factors limit the forecasting capacity of the projection exercise, apart from the uncertainty that inherently characterizes scenario analysis, particularly in a climatic context. In the first place, no policy responses or macroeconomic adjustments are contemplated. They would make it possible to cushion an eventual widening of the current account deficit in the long term, such as a real depreciation, cuts in public spending or variations in oil production in the face of price fluctuations. Including endogenous variables in the estimates would require a general equilibrium model in which the Colombian economy accommodates the shocks described in this study. However, the general equilibrium models with macroeconomic variables used in the NGFS projections do not extend to Colombia, an aspect that makes it difficult to include these adjustments.

Likewise, there is no sectoral or financial information to measure the incidence of physical risks (e.g. deterioration of transport infrastructure; shocks to agricultural productivity, among others) or some transition risks (increase in external borrowing costs) on the differences in the current balance between scenarios. Therefore, the results presented here only illustrate some of the possible paths for the current balance and should be interpreted mainly as an extreme measure of the expected effect on the trade balance. However, despite these limitations, the estimated model captures 90% of the variation observed in the current balance during the last decades. A degree of adjustment that reflects the relevance of the selected determinants.

4.1. Determinants of the current account

The selection of the current account's determinants was based on a literature review focused on studies that included empirical exercises to estimate the current balance[10]. We found that the factors that generally affect the behavior of this variable are the dependent population, public debt, GDP per capita, oil price, foreign interest rate and life expectancy (Table 1). The set of variables to include in the estimation was limited by the availability of prospective data since there are no projections for some of the current account drivers. Variables like net foreign assets, the degree of financial depth, the terms of trade and the value of oil exports. However, even if we could obtain trajectories for these variables, the current balance deviations would remain since these are determined by the factors

[10] Table A.1 summarizes the literature consulted to identify the determinants of the current balance, specifying the studies that analyze the factors described in Table 1 and indicating the effect found on the variable of interest.

already included in the NGFS climate scenarios. Therefore, the paths corresponding to some of these variables would not vary among scenarios, so their inclusion would not necessarily alter the study results. The frequency of the data is annual, and the period of analysis corresponds to 1997-2020, a choice determined by the availability of information and institutional reforms.

Table 1. Current account balance and its determinants

Variable	Description	Source	Expected effect
Current account blance	Current account balance as a percentage of GDP	Central Bank of Colombia	
Population dependency ratio	Population over 64 years of age as a proportion of the total of work force	National Administrative Department of Statistics of Colombia (DANE)	Negative
Public debt	Stock of total central government debt as a percentage of GDP	Ministry of Finance - Colombia	Negative
GDP per capita	Gross domestic product per capita	Central Bank of Colombia	Negative
Oil price	WTI oil price (*West Texas Intermediate*)	US Energy information administration	Positive
Foreign interest rate	United States Federal Reserve Interest Rates	Federal reserve	Positive
Life expectancy	Life expectancy at birth	National Administrative Department of Statistics of Colombia (DANE)	Positive

Note: Although the demographic variables do not vary between scenarios, they were included among the determinants of the current balance due to their importance in explaining the variation in this variable during the analysis period.
Source: authors' elaboration.

The expected effect of each determinant may differ between studies and ultimately depends on factors specific to each context, such as the country, the period of analysis, the frequency of the data, the number of observations, the units of measurement and the estimation technique. However, we found that, in general, the effect of the determinants proposed in this exercise can be described as follows: the increase in the dependent population reduces national savings as retirees use their savings, reducing the value of net foreign assets, which in turn drives a current deficit (Ojeda-Joya and Torres, 2012; Khan *et al*., 2002; Lane and Milesi-Ferretti, 2002). Public debt exhibits a similar effect, although channeled through increases in public spending. These effects are offset by increases in life expectancy, a factor that favors national savings (Backus *et al*., 2014). Increases in GDP per capita have a negative effect, since higher growth is associated with the domestic demand strengthening, which results in higher imports. Positive changes in the oil price improve the terms of trade, increasing the exports value. Finally, a higher interest rate in the United States causes capital outflows from emerging economies and tightens their external financing conditions, producing a real depreciation that improves the country's competitiveness and boosts exports, positively impacting the current balance.

4.2. Estimation method

The long-term relationship between the current balance and its determinants was estimated using an autoregressive vector model with the fully modified least squares method – FMOLS-. This technique, proposed by Phillips and Hansen (1990), mitigates endogeneity problems due to simultaneous causality caused by a cointegration relationship among regressors with a unit root. Anticipating that some of the determinants contain a unit root and that there may be a cointegration vector between some of them, we apply the extension proposed by Phillips (1995). It allows estimations that include series with a unit root –in addition to stationary series– without affecting the statistical inference since the estimators that result from this method exhibit an asymptotic normal-mixed (normal) distribution for the series with a unit root (stationary)[11].

To verify the existence of a unit root in the series of current balance determinants, as well as a possible cointegration relationship between them, we applied the augmented Dickey-Fuller and Engle-Granger tests, respectively. Results are presented in Table 2[12]. According to these, the external interest rate is stationary, the oil price has a unit root, and the other variables contain two unit roots. Hence, the latter

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[11] When this problem occurs, the ordinary least squares estimators exhibit a non-Gaussian, skewed, and asymmetric asymptotic distribution, invalidating the estimation results (Wang and Wu, 2012).

[12] To corroborate the findings of the augmented Dickey-Fuller test, a Phillips-Perron test was carried out, the results of which confirm the need to differentiate the dependent population, GDP per capita, public debt and life expectancy before the VAR estimation through fully modified least squares (Table A.2).

variables must be differentiated to be included in the estimates (Table 2a)[13]. The results of the Engle-Granger test indicate that there is indeed a cointegration relationship between the variables of the system, validating the estimation of the current balance using fully modified least squares (Table 2b)[14].

Table 2. Unit root and cointegration tests for current balance's determinants

a. Augmented Dickey-Fuller test

Variable	Series in levels	1st difference	2nd difference	Test result
Population dependancy ratio	-4,405	-2,164	1,681 **	I(2)
Log GDP per capita	-1,381	-1,041	-4,352 ***	I(2)
Public debt	0,793	-0,792	-5,769 ***	I(2)
Foreign interest rate	-4,027 **	-	-	I(0)
Oil price	-1,195	-4,974 ***	-	I(1)
Life expectancy	-2,287	-0,536	-4,839 ***	I(2)

Note: The null hypothesis of the augmented Dickey-Fuller test establishes that the analyzed series contains a unit root. To perform the test, the Schwarz information criterion is set. *, **, *** indicate rejection of the null hypothesis with confidence levels of 90%, 95% and 99%, respectively.

b. Engle - Granger test

Variable dependiente: balance de cuenta corriente entre 1997 y 2020.		
Determinants: public debt; population dependancy ratio; log GDP per capita; life expectancy; foreign interest rate; oil price		
	Statistic	**P-Value**
Engle-Granger statistic	-7,780	0,018
Null hypothesis: there is no cointegration relationship between the system variables.		
Specification: lag-free test using the Schwarz information criterion[15]		

Note: The estimation equation includes public debt, the population dependency ratio, GDP per capita, life expectancy, the oil price as I (1) and the foreign interest rate I(0), with the coefficients being estimates the long-term cointegration between the determinants and the dependent variable.
Source: authors' elaboration.

[13] The series containing more than one unit root show an important trend component during the study period. For example, the dependent population and life expectancy exhibited a sustained increase in recent decades, reflecting general changes in demographic patterns, such as the population aging and advances in quality of life. Meanwhile, central government debt as a percentage of GDP rose to 59% after hovering around 13% in the mid-1990s, an increase that reflects institutional changes that had a considerable impact on public spending.
[14] To corroborate the results of the Engle-Granger cointegration test, the augmented Dickey-Fuller test was performed for the residuals resulting from the estimation of the current balance and its determinants, whose results indicate a stationary behavior, in such a way that the series exhibit a long-run cointegration relationship.
[15] The results of the Augmented Dickey-Fuller and Engle-Granger tests are robust to the information criterion used to detect unit root and cointegration.

The Table 3 shows the results of the long-term relationship between the current account balance and its determinants. Most of the determinants proposed for this exercise are statistically significant and exhibit the expected sign -in agreement with the literature–. The growth rates of the dependent population and GDP per capita are the two determinants with the greatest incidence on the current balance dynamics. It should be noted that the prediction of the current balance exhibits a robust fit with respect to the observed series, since the variation in the proposed determinants explains 87% of the variation in the dependent variable.

Table 3. Estimation of the long-run relationship between the current account balance and its determinants (1997 – 2020).

Dependent variable: current account balance			
Determinants	**Coefficient**	**Standard error**	**P-Value**
Public debt growth	-0,042	-1,680	0,093
Population dependancy growth	-18,997	-19,07	0,000
GDP per capita growth	-25,429	-8,950	0,000
Life expectancy change	3,073	5,660	0,000
Foreign interest rate	0,030	0,950	0,342
Log oil price	0,471	2,760	0,006
Constant	-0,558	-0,780	0,435
R-square	0,875		
Adjusted R-square	0,825		
Standard error	0,738		
Long-run standard error	0,218		

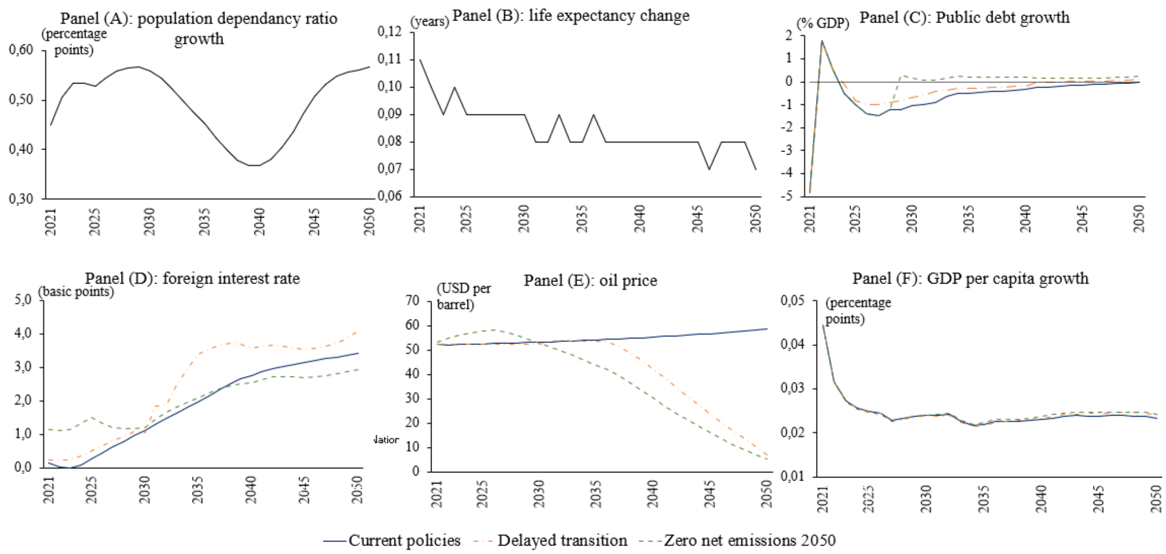
Note: the series corresponding to the population dependency ratio, life expectancy, the total debt of the Central Government and the logarithm of GDP per capita contain two unit roots, which is why they were differentiated before being included in the estimates, in such a way that so that the change in these variables represents growth. Source: authors' elaboration.

5. Current account balance projection

To project the current account balance, we employed the estimated long-term relationships between this variable and its determinants and used the forecasted trajectories for these under different climate scenarios (Graph 2). The paths for public debt and GDP per capita are based on the projections presented in Bernal *et al*. (2022). Under a continuity of current climate policies, public spending on mitigation and adaptation to climate change is constant and represents 19.6% of annual GDP. Oil revenue initially contributes 0.6% of GDP and decreases by 0.2 p.p. by 2050 due to an energy transition that cuts this source of tax revenue. Under a delayed transition scenario, government spending on climate change would increase by 0.4 p.p. GDP and oil revenues would fall by 0.4 p.p.

In the event of reaching zero net emissions in 2050, spending on climate change would increase by 0.6 p.p. GDP, while oil revenues would disappear at the end of the current decade.

Graph 2. Path of the determinants of the current balance under different climate scenarios (202 1-2050).



Source: Network for the Greening of the Financial System (NGFS), National Administrative Department of Statistics of Colombia (DANE) and Bernal *et al.* (2022).

Regarding GDP per capita, the projections of Bernal *et al*. (2022) show that the GDP under current climate policies would reduce by approximately 8% by 2100. The expected losses in the scenarios with the implementation of climate change mitigating measures would be between 2% and 3% of GDP. Consistent with the above, economic growth rates would be higher in the delayed transition and zero net emissions scenarios by 2050, highlighting the capacity of physical risks to affect economic activity.

The paths corresponding to the oil price and the external interest rate come from the NGFS projections[16]. In particular, the oil price behavior reflects the differences in the climate policy of the different scenarios. Under the continuity of current policies, this variable would maintain an upward trajectory, which is expected considering the absence of tangible efforts aimed at containing this phenomenon. However, in the other scenarios, the trajectory shows the introduction of measures to promote the fulfillment of climate goals. In the net zero emissions scenario, the price of oil would present an immediate increase attributable to the imposition of carbon taxes. However, an eventual

[16] NGFS (2021) contains the details related to the projection of these variables

transition to renewable energy sources would cause a permanent drop from the end of the current decade.

In the models used by the NGFS, monetary policy reacts to contain inflation and depends, to a large extent, on the dynamics associated with energy prices. Under zero net emissions, the FED's intervention rate increases to offset the positive shock to the oil price. The same answer arises, albeit with some retard in the delayed transition scenario. In the current policies scenario, the path of this variable follows a growing trajectory, along with the oil price.

The dependent population and life expectancy come from the demographic projections of the National Administrative Department of Statistics; they do not vary between scenarios and capture the demographic trends expected in Colombia during the following decades. According to Parra *et al*. (2020), a sustained decline in fertility would cause an aging population, increasing the proportion of retirees who depend on transfers for their subsistence with respect to the population with capacity to generate savings. Likewise, it is expected that the gradual increase in life expectancy will continue, an aspect that reflects the advances in the quality of life.

5.1. Results

Graph 3 shows the expected trajectory of the current account balance between 2021 and 2050 under the climate scenarios described in Section 2. There is an increase in the current account deficit in the short term, which can be explained by three aspects: an increase of the dependency relationship; the indebtedness of the Central Government due to the implementation of programs to alleviate the economic impacts of the COVID-19 pandemic; and GDP per capita growth as economic activity normalizes after the negative shock caused by the pandemic.

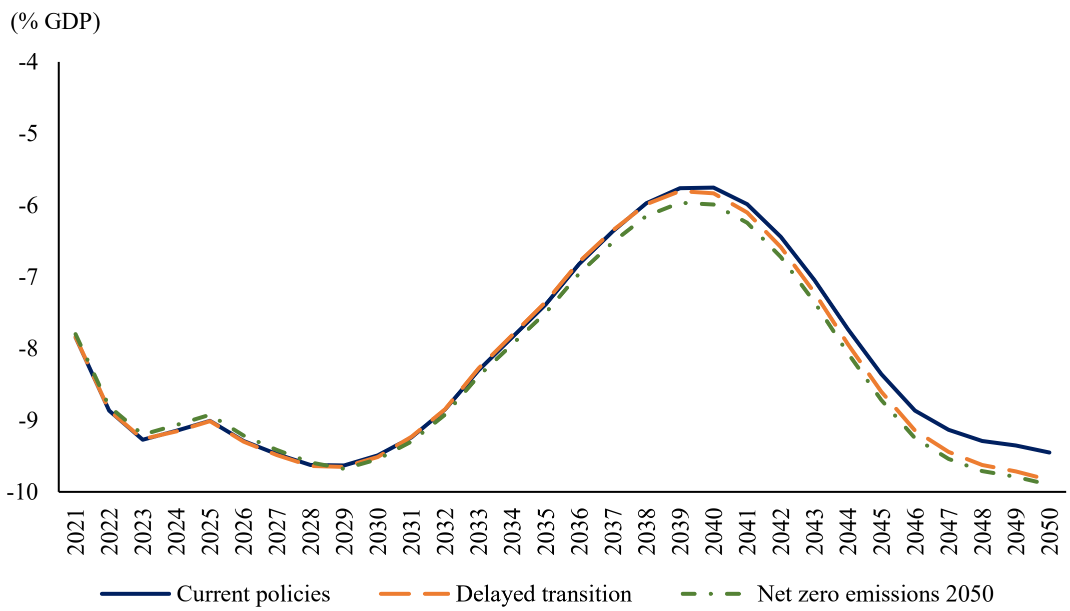
In the long term, the path of the current balance would be determined by the growth rates of the dependent population and by the oil price[17]. Specifically, at the beginning of the following decade a decrease in the dependency ratio is expected. In this sense, the country would reach the lowest current deficit by 2040. However, a new demographic change would reverse the downward trend in this variable, causing further increases of the current account deficit[18]. In scenarios with a high incidence

[17] The other determinant with a statistically relevant and large effect, GDP per capita, would present few variations in its future behavior, so its contribution to fluctuations in the current balance would be limited. Likewise, although public debt constitutes a factor with statistical relevance for which important changes are expected during the coming decades, the magnitude of its effect is comparatively low, so its incidence on the expected trajectory of the current balance is moderate.

[18] This is consistent with Parra *et al*. (2020), where demographic projections show a gradual aging of the population due to a drop in the fertility rate as of 2030. This would cause a decrease (increase) in the proportion of the working age population (65 years or more), which explains the expected increase in the dependency ratio.

of transition risks, the above effects would be exacerbated by a permanent drop in oil prices, a factor that would deepen the deterioration of the external position.

Graph 3. Projection of the current balance under different climate scenarios (2021-2050).



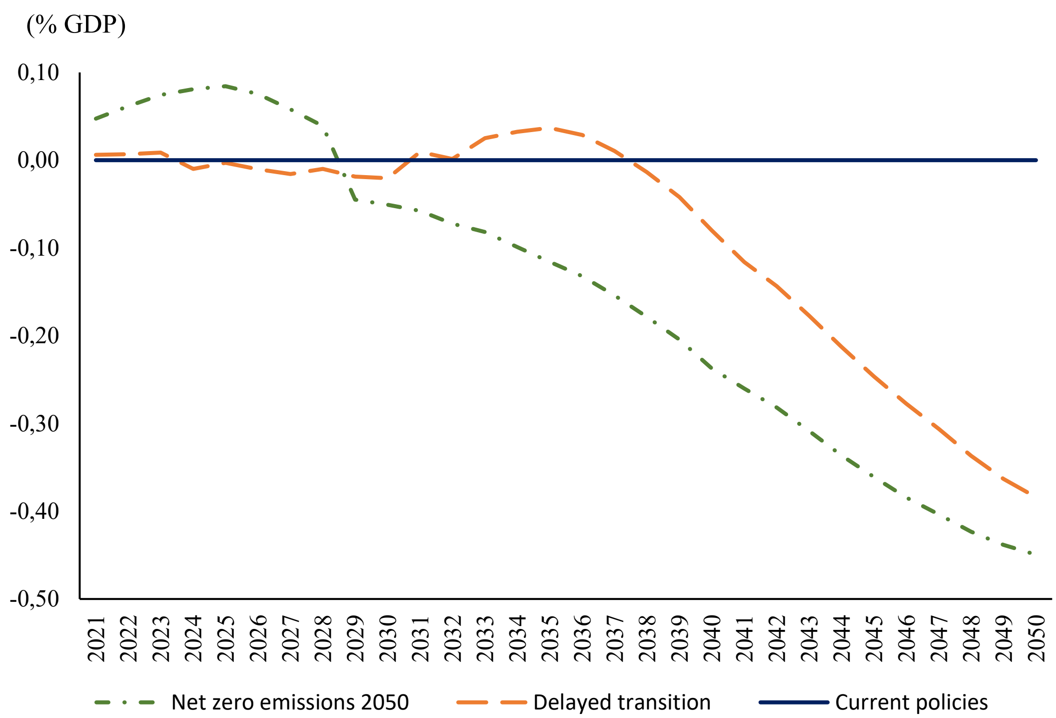
Source: author's elaboration.

5.2. Effects of risks associated with climate change on the long-term current balance in Colombia

Graph 4 shows the current balance deviations between the different climate scenarios considered in this study, using as a reference the one that assumes a continuity of current climate policies: positive (negative) values indicate a current surplus (deficit) in relation to the reference scenario. The results of this calculation suggest that the long-term current deficit would be higher in scenarios where a robust climate policy is adopted. This deterioration would be mediated by a fall –relative to the reference scenario– in external and fiscal income due to negative shocks in the oil price and increases in public debt.

In the scenario of zero net emissions in 2050, there would be a transitory increase in the oil price, which would improve the terms of trade and the balance in the short-term, relative to other scenarios where current climate policies remain until 2030 or plus. This impulse, however, would be dissipated by an eventual transition towards renewable energy sources and the subsequent permanent drop in the oil price, leading to a gradual expansion of the current account deficit[19]. Additionally, under zero net emissions, the long-term public debt would be at higher levels due to increases in public spending aimed at mitigating climate change in order to meet the climate goals of the scenario, a factor that would deepen the deterioration in the external position of the country (Bernal *et al*., 2022).

Graph 4. Deviations in the current account balance between climate scenarios (2021-2050).



Note: This graph shows the current balance deviations, in percentage points of GDP, between different climate scenarios, using the current policies scenario as a reference. Positive (negative) values indicate a lower (higher) current deficit relative to the reference scenario.
Source: author's elaboration.

A similar situation is anticipated under a delayed transition, although in this case the expected deterioration of the current account would occur towards the end of the next decade. Unlike the previous case, the initial transitory increase in the price of oil would be lower, an aspect that is explained by a less far-reaching climate policy, reflected in lower carbon taxes (Graph A.1). Precisely for this reason, the fall in the final price of oil in the long term would be smaller, which would contain the expected deterioration of the current balance. Additionally, in this scenario, public finances would

[19] In the current policy scenario, the oil price remains at relatively high levels and even shows future increases.

be favored by a comparatively lower public debt due to reduced public spending oriented towards climate change.

6. Conclusion

The external sector in Colombia exhibits a high degree of vulnerability to the risks associated with climate change. The projection of the current balance under different climate scenarios indicates that the orderly achievement of zero net emissions in 2050 could widen the current deficit in Colombia by the end of the current decade – relative to the continuity of current climate policies. Specifically, we find that the accumulated net cost on the current balance associated with meeting the climate goals under the zero-emissions scenario would amount to 4.6% of the annual GDP. This increase would be mediated by a permanent drop in the oil price and an increase in public debt. In the event of a delayed transition, this cost would reach 2.6% of annual GDP.

Regardless of how the transition to a low carbon economy unfolds, our results indicate that the implementation of climate change mitigating policies would deteriorate the country's external position in the long term. Likewise, they emphasize the potential of transition risks to affect economic activity since the negative effect on the current balance would arise despite a lower incidence of physical risks, which would generate losses of 6% of GDP by 2100 in the event of maintaining current climate policies[20].

Other factors that were not included in the current balance projection due to information limitations could affect the long-term external position. According to Paltsev (2012), negative shocks to agricultural productivity would cause increases in food prices, which could improve the terms of trade between countries with export potential in this sector, as is the case of Colombia. On the contrary, the expected deterioration in the transport infrastructure, added to an increase in external borrowing costs due to the contraction of oil revenues, could deepen the long-term current deficit. Ultimately, the final effect depends on the magnitude of the impacts associated with physical and transition risks, which exert opposite effects on the current balance and for which there is a high degree of uncertainty.

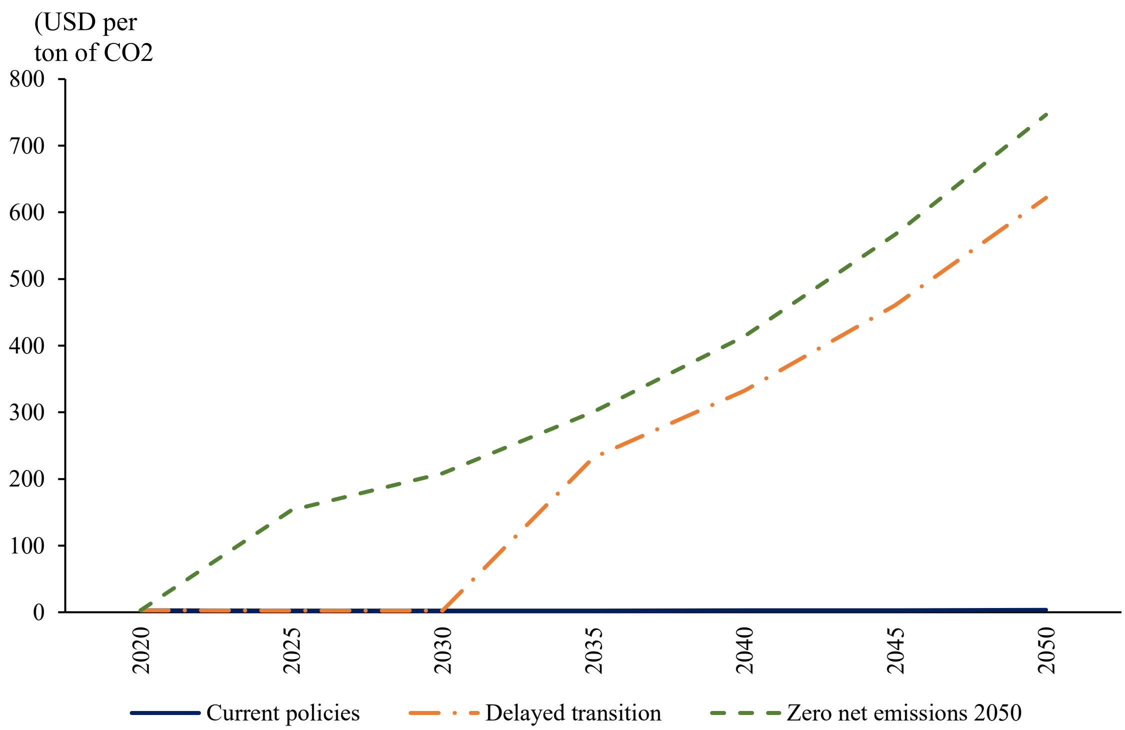
Finally, it is worth taking into account that the transition risks analyzed in this study result from changes in external factors such as the oil price, on which Colombia has little influence, as it is a small and open economy, (Perilla, 2011). Therefore, and considering the increasing probability of

[20] According to the results reported in Bernal *et al*. (2022), the continuation of current climate policies would lead to a loss equivalent to 7.8% of GDP by 2100. This loss would be 2.0% under a scenario of zero net emissions by 2050.

climate scenarios with energy transition and the importance of this factor in explaining the differences in the long-term current account, it is imperative that the country generate alternatives to replace oil revenues (Garavito *et al*., 2020). This would make it possible to reduce vulnerability to this type of shocks, possibly mitigating the expected impact on external income.

7. Appendix

Graph A.1. Carbon price path under different climate scenarios (2021-2050).



Source: Network for Greening the Financial System (NGFS).

Table A.1. Determinants of the current account — literature review.

Author(s)	Year	Country	Category	Frequency	Time period	(1)	(2)	(3)	(4)	(5)	(6)
Arteaga *et al.*	2011	Colombia	Developing	Quarterly	1994q1-2010q4	✓					
Cheung *et al.*	2013	22 AE; 72 DE	Both	Annual	1973-2008	✓					
Chinn and Prasad	2003	18 AE; 71 DE	Both	Annual	1971-1995	✓					
Das	2016	27 AE; 79 DE	Both	Annual	1980-2011						
Debelle and Faruqee	1996	21 AE	Advance	Annual	1971-1993	✓					
Lee *et al.*	2008	22 AE; 32 DE	Both	Annual	1973-2004	✓					
Moral-Benito and Viani	2017	Spain	Advance	Annual	1980-2015	✓	✓		✓		
Ojeda-Joya	2019	Colombia	Developing	Annual	1986-2017				✓	✓	
Phillips *et al.*	2013	49	Both	Annual	1986-2010	✓					
Backus *et al.*	2014	3 AE; 1 DE	Both	Annual	1980-2013						✓
Lane y Milesi-Ferretti	2002	39 DE	Developing	Annual	1970-1998		✓	✓			
Sadiku *et al.*	2015	Macedonia	Developing	Quarterly	1998q1-2013q4						

(1) Population dependancy
(2) Public debt
(3) GDP per capita
(4) Oil price
(5) Foreign interest rate
(6) Life expectancy

Negative and significant effect
Positive and significand effect

Note: AE denotes advanced economies; DE denotes developing economies. This table does not include an exhaustive list of the determinants used in the listed studies, but rather indicates whether the determinants used in this exercise were considered in those studies.
Source: author's elaboration.

Table A.2. Unit root test - (Phillips-Perron)

Variable	Series in levels	1st difference	2nd difference	Result
Population dependancy ratio	1,518	-2,652	-5,674 ***	I(2)
Log GDP per capita	-1,858	-0,066	-6,405 ***	I(2)
Public debt	0,496	-1,924	-5,766 ***	I(2)
Foreign interest rate	-1,892 *	-	-	I(0)
Oil price	-1,669	-4,661 ***	-	I(1)
Life expectancy	-2,906	-1,507	-4,163 ***	I(2)

Note: the null hypothesis of the Phillips-Perron test establishes that the analyzed series contains a unit root. *, **, *** indicate rejection of the null hypothesis with confidence levels of 90%, 95% and 99%, respectively.
Source: authors' elaboration.

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