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Rural Population and COVID-19: A Model for Assessing the Economic Effects of Drop-Out in Higher Education

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Higher education is one of the ways to overcome social inequalities in rural areas in developing countries. This has led states to develop public policies aimed at access, retention and timely graduation of students in those sectors, yet the high drop-out rates among the rural student population, which were catalysed by COVID-19, prevent the intrinsic and extrinsic benefits of obtaining a higher education degree from materialising. Thus, the study of the phenomenon of dropout before and after the pandemic has not sufficiently addressed the economic issues raised by this phenomenon for the different actors at the educational level. The purpose of this paper is to model the economic effects of rural student dropout at the higher education level for students and families, Higher Education Institutions (HEIs) and the State, based on public policies for access to higher education, in the pandemic and post-pandemic scenario. In order to delimit the operationalisation of the proposed model, a set of undergraduate training programmes in Colombia was taken as a reference. System dynamics was used as the main modelling technique. The model was based on data from the 20 training programmes with the highest number of students enrolled in rural areas for the year 2019, by running three computational simulations. The results showed the description of the dynamic model and the financial effects of dropout for the actors of the educational level with the current policies of access to higher education, the scenario in which COVID-19 would not have occurred and the consolidation of the public policy of tuition fee exemption in public HEIs as a result of the pandemic. It was concluded that the model developed is very useful for the valuation of these economic effects and for decision-making on policies to be implemented, given that the costs of dropout are characterised by high costs for students and their families as well as for HEIs, and where it was determined that current policies are inefficient in preventing and mitigating dropout.

Keywords: drop-out, COVID-19, rurality, model, economic effects, higher education

INTRODUCTION

Higher education has been conceived as a way to overcome social inequalities in developing countries (Marginson, 2011; OECD 2015; Herbaut and Geven, 2020; Guzmán et al., 2021a), hence, the interest of the states to intervene through the development of public policies with the aim of facilitating access, permanence and timely graduation of students at this level of education (Herbaut and Geven, 2020). That said, it is recognised that there are a number of population groups where social inequalities are more pronounced, especially those located in rural areas. This was confirmed by the United Nations when it stated that by the year 2020, 80% of the world's poor people would live in rural areas, and that in some countries the majority of the population would be concentrated in rural areas (United Nations, 2021).

In this context, public policies developed by states to facilitate access, retention and timely graduation of students in rural areas of developing countries, especially in developing countries, have been based on a paradigm in which the state assumes the role of funder of students (Marginson, 2016; McCowan, 2016). In this way, the State finances tuition under the form of educational credits or tuition fee exemptions, either totally or partially, where in the latter case, it relies on the Higher Education Institutions (HEI), the family or the student him/herself to cover the totality of the expenses.

Although there has been a generalised concern on the part of states regarding access, retention and timely graduation in higher education for rural populations, it is necessary to recognise that the strategies used for financing bring with them multiple effects for the actors at the educational level (student and family, HEI, State, among others), especially when there are high dropout rates in this student population, as exemplified in the Colombian case where the Ministry of National Education (Ministry of National Education, 2009) indicated that the dropout rate per cohort was close to 50%. Taking into consideration what was previously stated added to the context of the COVID-19 pandemic, it has been identified as a catalyst for problems at the educational level (e.g: Pokhrel and Chhetri, 2021; Dennis, 2020; Mailizar et al., 2020; Abbasi et al., 2020; Sobaih et al., 2020; Favale et al., 2020; Basilaia and Kvavadze, 2020; Kerres, 2020; Wang et al., 2020), including dropout levels among the most vulnerable populations (Guzmán et al., 2021a; United Nations, 2020), Hence, a critical analysis of the economic effects of this pandemic on education stakeholders related to the drop-out phenomenon is required.

In this sense, both public policy makers and researchers at the higher education level have not analysed in detail, either before or during the pandemic, the financial problems caused by drop-out in rural populations for students and their families, HEIs and the state, within the framework of public policies for financing higher education. This is largely due to the lack of robust models that allow the valuation of the economic effects of dropout, as well as the general interest of the academic community in analysing other aspects of the COVID-19 pandemic for this student population, such as the use of and access to technological resources (Cameron-Standerford et al., 2020).

In this context, the analysis of the economic effects of dropout in the framework of public higher education funding policies, prior to and during COVID-19, has been characterised by being clustered at the national or state level (e.g.: Sahoo et al., 2021; Dennis, 2020; World Bank, 2020; Denning, 2017; Richburg-Hayes et al., 2015; Bettinger, 2015), or, cases of individual studies in an HEI (e.g.: Bernal, 2018; Barragán and Rodríguez, 2015), for which there is not a panorama reflecting the realities of rural students. In addition, the improvements developed are not usually of a holistic nature and integrate the actors at the educational level, but are characterised by being individualised for each of the actors (student and family, HEI or State), especially in the field of modelling (e.g: Cristia and Pulido 2020; Moreno et al., 2019, Sosu and Pheunpha 2019; Hällsten 2017; Fack and Grenet 2015; Rubin 2011; Qu, 2009).

Considering the public policies of access to education, the phenomenon of dropout in rural populations, the effects that COVID-19 has had on the educational level, the fragmentary analysis of the economic effects of dropout and the lack of models that integrate the actors of the educational level, especially in rural populations, the aim of this article was to model the economic effects of rural student dropout at the higher education level for students and families, HEIs and the state, based on public policies for access to higher education, in the pandemic and post-pandemic scenario. For the operationalisation of the proposed model, a set of undergraduate training programmes in Colombia was taken as a reference.

The selection of Colombia for the operationalisation of the model is due to the various social disparities experienced in the country, which are directly or indirectly related to the level of education, and which have been catalysed by COVID-19 especially in rural areas, such as: high levels of poverty, low employability, poor accessibility to basic services such as electricity and internet, unequal access to information and communication technologies, among others. This was made evident in the Agronet Report (2020), where in rural areas 44,362 people became newly unemployed and 108,000 unemployed 2 weeks after the declaration of the national health emergency, and the contraction of the economy has affected the rural population, leading to a generalised decrease in food prices and, therefore, in the income of this population.

With the fulfilment of the objective, various contributions are made to the analysis of the problem of drop-out in the rural student population. Firstly, this article complements the advances in the understanding of both the economic effects of dropout in the framework of COVID-19 and its modelling, as it concerns all higher education actors; this complementation is based on the methodological contribution in terms of dynamic modelling, adding a holistic perspective to the analysis in relation to rural populations, as well as a more robust model for the understanding of the studied phenomenon. Secondly, this article provides feedback to the managers of public policies on the financing of higher education based on credit and tuition fee waivers with the aim of maintaining, modifying or eliminating them, in order to mitigate to some extent the financial consequences of dropout and overcome the social inequalities experienced in rural areas of developing countries.

Thirdly, the model makes it easier for direct and indirect users of educational access policies to make informed decisions by recognising the economic effects of dropping out.

This article is divided into five sections. The first one was the introductory overview and justification; the second concerns the theoretical framework and proposed model, which presents the conceptualisation of dropout, the documented economic effects on education stakeholders and concludes with the proposed dynamic model; the third concerns the methodology used for the fulfilment of the objective and for the operationalisation of the model through the use of system dynamics; the fourth reports on the design of the model and the results of the computational simulations developed; and the fifth discusses the main findings and incorporates the conclusions.

THEORETICAL FRAMEWORK AND PROPOSED MODEL

Drop-Out

Student drop-out as an educational phenomenon does not have a single meaning, but rather there are multiple definitions in the literature and public policies. This is a result of the complexity of this phenomenon which involves several levels of analysis as stated by Guzmán et al. (2021a), Guzmán et al. (2021b) and Kehm et al. (2019). In this sense, this variety of conceptualisations allows for a broader understanding of dropout because it links different aspects, variables, representations, models and effects of dropping-out.

Taking into consideration what was previously stated, the meanings can be categorised as theoretical and operational. In the case of the theoretical ones, they obey those provided by the academic community in which the interaction of multiple explanatory variables of the drop-out phenomenon is contemplated, such as the one given in the framework of the ALFA GUIA project in which this phenomenon was defined as "the cessation of the relationship between the student and the training programme leading to the award of a Higher Education degree, before achieving the degree. It is also an event of a complex, multidimensional and systemic nature, which can be understood as cause or effect, failure or reorientation of a training process, choice or obligatory response, or as an indicator of the quality of the education system" (Proyecto ALFA GUIA DCI-ALA/2010/94, 2013, p. 6); or, as explained by Zuñiga (2006), the student's decision to terminate his or her training process in advance of its completion.

The second category corresponds to the operational meanings developed by public policies, which facilitate the measurement of drop-out at the higher education level, as well as the evaluation and monitoring of some variables. In the Colombian case, this definition is given according to the time in which a student was not linked to the HEI, being considered a deserter if he/she has not legalised enrolment in two consecutive academic periods, and if he/she has not graduated or dropped out (Ministry of National Education, 2009). This article falls into the latter category, as it facilitates time-dependent counts, allowing the economic effects of the phenomenon to be modelled and assessed.

Recognising drop-out is a multifactorial circumstance and based on the nature of the objective of this article, its study is based on an economistic approach which seeks to understand which socio-economic variables influence students' decision to end their education process early, as well as the effects of this decision on higher education stakeholders. In this respect, the preference of various authors for investigating the socio-economic context of the student, the identification and treatment of this type of variable as presented in the studies developed by Rodríguez-Hernández et al. (2020), Palacio Sprockel et al. (2020), Adrogue and García (2018), De Clercq et al. (2017), Erola et al. (2016), among others. This same situation is present in the study of dropout in rural higher education, as evidenced in the works of (Cook et al., 2021; Mncube et al., 2021; Guzmán et al., 2021b; Castleman and Meyer, 2020; Ramírez et al., 2020; Lewine et al., 2019; Muñoz, 2013; De Hart and Venter, 2013; Qu, 2009).

However, the literature concerning the economic effects of drop-out for higher education stakeholders has not been widely addressed, especially from the perspective of public policies on access, retention and timely graduation. Thus, Herbaut and Geven (2020) indicated that in recent years this type of financial consequences have received increasing, but still insufficient, attention. Studies have shown that this type of policy has the capacity to reduce the drop-out rate and increase the graduation rate in the medium term, representing a higher level of indebtedness for students and their families, as well as a lower stranded cost for HEIs. However, from the approach of these policies it has also been observed that in the long term they lose the capacity to reduce this rate once the expected result of the implementation of public policies of access to higher education based on credit has been achieved (Mayer et al., 2015). In the case of HEIs, research has quantified the stranded costs of drop-out and the effects they have on their substantive functions (e.g.: Barragán and Rodríguez, 2015). Finally, the economic effects of this phenomenon on states have been linked to its potential to mitigate the improvement in the income of the population (Cristia and Pulido 2020) and its inability to increase productivity (Atchoarena et al., 2005; McMahon, 2010), lacking an analysis of higher education access policies that are implemented for specific educational populations.

Based on this theoretical framework, the economic effects of drop-out on students and their families, HEIs and the state are presented below in the context of public policies on access to higher education.

Economic Effects of Drop-Out on the Student and Family

Human Capital Theory, consolidated by Becker (1962), suggests that the student and his family are rational actors who base their decision to invest in education on comparing the costs (e.g. tuition values, possible sunk costs, etc.) and the monetary benefits (e.g. wages, rental income, etc.) of higher educational achievement (Marginson, 2019). The student and his or her

family will make the decision to continue their education according to the short, medium and long term economic benefits for them (Marginson, 2019; Didenko, 2015 cited by; Gruzina et al., 2021). Thus, they will make a joint decision to enter higher education, comparing the cost of tuition fees at HEIs, the possibilities of financing with their own resources (Qu, 2009) or the possibility of financing with public or private entities (Nizar and Nazir, 2020; Suhendra, 2020). In this way, of the total number of applicants (high school graduates), only those students who have the financial capacity or who perceive some benefit or a better opportunity cost of higher education in the terms expressed in the Human Capital Theory will be admitted (Chen and DesJardins, 2008; Chen and DesJardins, 2010; Özdoğan, 2021).

In other words, it is understood that the more academic periods a student spends in higher education, the greater the investment made, and consequently in the event of the student dropping out, the higher the investment will be if the student decides to interrupt the process due to the influence of individual variables, (Arias-Velandia et al., 2018; Behr et al., 2020), socioeconomics (Contreras, 2018; Palacio Sprockel et al., 2020; Schmitt et al., 2020), academics (Guzmán, et al., 2020; Heidrich et al., 2018) and institutional variables (Armstrong et al., 2018; Choi and Kim, 2018), as well as the higher the stranded cost will be for the student or the student's family (Larroucau, 2016; Laaser, 2018). In addition, by resorting to credits originating in public policies, the dropout student and his or her family will incur interest payments, which represents an increase in these costs (Moreno et al., 2019). Due to the existence of drop-outs, it is expected that the number of students enrolled in HEIs in this cohort will decrease (Barragán and González, 2017). Finally, the lack of timely graduation of students represents a major stranded cost when students drop out of school (OECD, 2017).

However, the literature has shown the impact caused by the COVID-19 pandemic on the graduation rate of rural high school graduates, represented in a lower number of students with this academic level and triggering a social crisis (Chatterji and Li, 2021; United Nations, 2021) as a result of not being able to attend classes and not having access to adequate Information and Communication Technologies to ensure their training process (Expósito and Marsollier, 2020; Mncube et al., 2021). On the other hand, COVID-19 has decreased the rate of access to higher education, due to the high costs that the educational level represents for the student and his family, as a result of the economic crisis and the social emergency, since they cannot cover the tuition and other costs associated with the educational level either with their own resources or with credits (Potra et al., 2021; United Nations, 2021). In addition, COVID-19 has led to a decrease in student retention in higher education, which implies a higher drop-out rate (Cruz et al., 2020; Alyoussef, 2021; Guzmán et al., 2021b; Delnoij et al., 2021; López-Aguilar and Álvarez-Pérez, 2021; Teuber et al., 2021).

Economic Effects of Drop-Out in HEIs

As in the case of students and their families, drop-out at the higher education level has a direct impact on the finances of HEIs by generating economic instability, especially in those that depend on tuition fees (private and mixed economy HEIs), and in the case of public HEIs, dropping out is seen as a waste of public funds (Choudhary and Hammayun, 2015; Esteban et al., 2017; Becerra et al., 2020).

In this sense, HEIs with a high drop-out rate have high opportunity costs, as they lose out on tuition fees for a number of periods not taken (Barragán and Rodríguez, 2015; Améstica-Rivas et al., 2020). Thus, it is presumed that the more academic periods a student attends, the lower the opportunity cost for HEIs will be. The quantification of the opportunity cost to HEIs resulting from dropping out has been of great interest in developing countries in view of the difficulties faced by institutions in ensuring their sustainability, particularly in developing countries. An example of this is the work developed by Bernal (2018) in which this cost was estimated for a Colombian HEI for the period 2011 to 2014, which amounted to 9,430,866,735 pesos (equivalent to USD 2,468,177), or the work developed by Améstica-Rivas et al. (2020) who estimated that the opportunity cost for Chilean HEIs was USD 23,000,000 for those students who had scholarship credits.

In addition to calculating this opportunity cost, the literature recognises that the higher the drop-out rate, the more difficulties HEIs face in the development of their substantive functions (teaching, research and social outreach), since they have fewer resources available for hiring teachers, training them, developing research projects, disseminating their results and managing links with the external sector, among other things (Voelkle and Sander, 2008). Consequently, the opportunity costs of student drop-out have a direct impact on the quality conditions of the programmes, as well as on the reputation of HEIs, leading to a decrease in the access rate to HEIs (Ortiz and Dehon, 2013; Basilaia and Kvavadze, 2020).

In contrast to the stranded cost of untimely graduation for the student and his/her family, for HEIs this becomes an unconsidered income which, although not directly related in the literature, can to some extent reduce the opportunity cost and the difficulties of drop-out in the substantive functions.

Economic Effects of Drop-Out for the State

In the case of the state, the economic effects of drop-out have been addressed in two ways. The first concerns the consequences on the economy in the short, medium and long term, this being the main line, where studies have indicated the loss of income and purchasing power by the student population who drop-out, which results in lower productivity for the State represented in a stagnation or decrease in Gross Domestic Product (Chetty et al., 2020; Hanushek and Woessmann, 2020); and the second, which concerns the monetary quantification of the drop-out in which this article is focused.

Thus, in the case of this second stream, previous research recognises that states, when they assume student fees, especially in public HEIs, assume a stranded cost (Choudhary and Hammayun, 2015), as stated by the World Bank (2020) " (. . .) students who do not graduate on time (or at all) when they receive public funding consume valuable fiscal resources, which in many cases are not recoverable" (p. 14). On the other hand, and based on the educational credit policy to facilitate access to higher

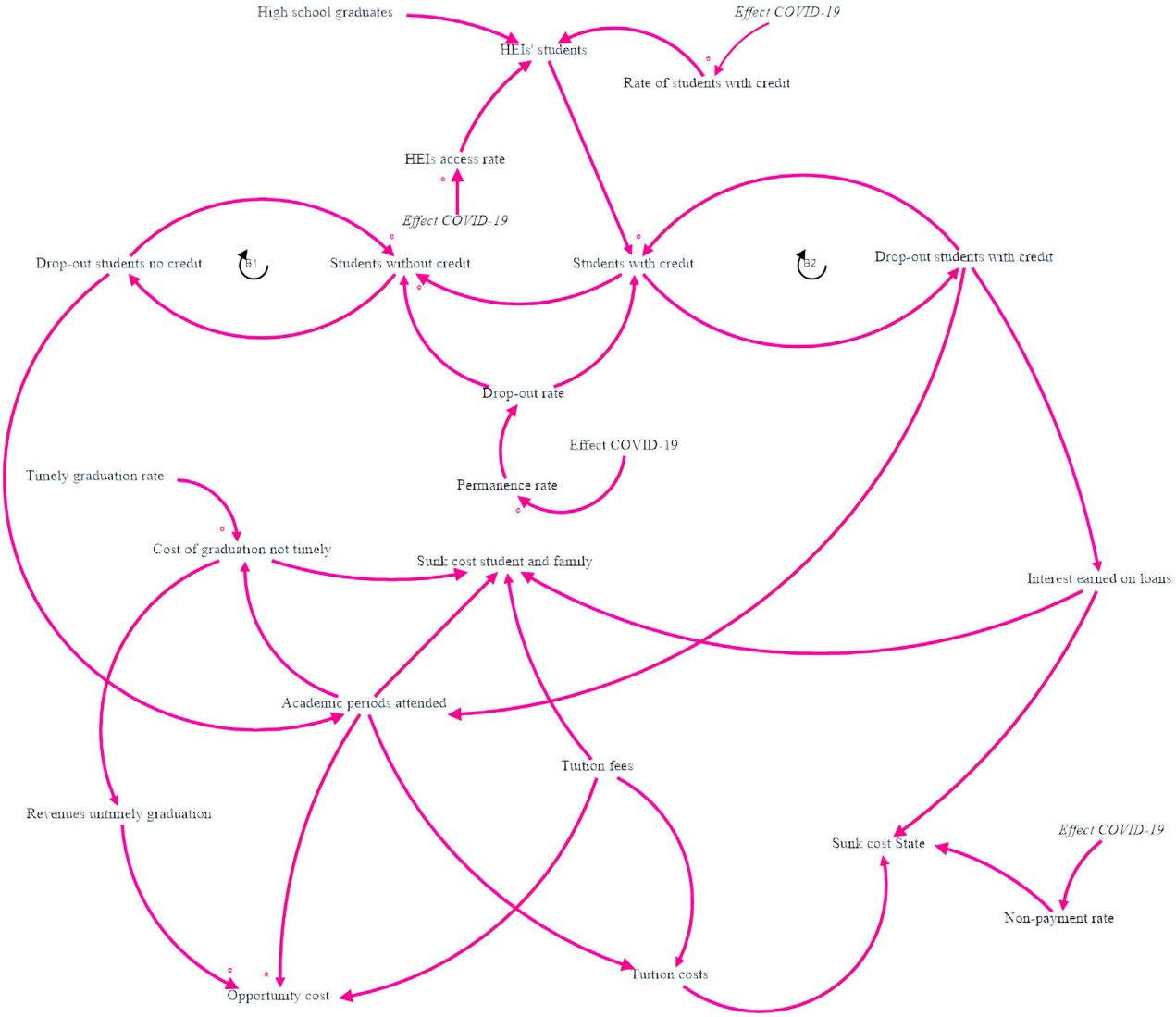

FIGURE 1 | Causal Loop Diagram. Note: B indicates that it is a balance loop. For the purposes of this diagram, positive relationships have no loadings on the connectors.

education, the states that implement it accept the risk of non-payment by students and their families (Moreno et al., 2019), which leads them to accept such a loss of resources, implying a de-financing of state programmes to grant credits (Améstica-Rivas et al., 2020; López-Aguilar and Álvarez-Pérez, 2021).

Proposed Dynamic Model

Based on the economic effects of drop-out for the student and family, HEIs and the state, as described in the preceding sections, a Causal Loop Diagram or dynamic hypothesis was designed (see **Figure 1**), in which the existing relationships between the variables of the system are synthesised.

High school graduates who are the potential population for admission to higher education undergo the admission process and, once accepted by a HEI, may choose to pay their tuition fees by means of a loan or use their own and their family's resources. Hence, two causal loops are formed. The first one (B1), relates students who did not have access to credits, who are affected by a drop-out rate which, being high, will represent a higher number of non-credit drop-outs and consequently a lower number of students. The second (B2) represents credit drop-outs who, like non-credit students, are affected by a drop-out rate, resulting in an increase in credit drop-outs. The higher the drop-out rate in either case, the lower the retention rate and the higher the stranded cost for the student and his/her family. The higher the number of academic periods completed, the higher the stranded cost due to the impact of variables such as the cost of untimely graduation, tuition fees and interest on credits.

As far as the opportunity cost of HEIs is concerned, this is determined by the cost of untimely graduation, given that the higher the number of academic periods taken in addition to

those established in the study plan, the lower the cost will be, generating unforeseen income for the HEI, provided that they are private. In the case of public HEIs, the cost of untimely graduation represents a detriment to the state. On the other hand, the earlier students drop-out, i.e. the earlier they have completed fewer academic terms, the higher the opportunity cost.

In the case of the stranded cost of the state, this will be the result of the value of the tuition fees of students who drop out of public HEIs and the rate of non-payment of credits granted in the framework of public policies for access to higher education. Finally, COVID-19 influences multiple variables that cause the behaviour of the system to vary, such as the number of new entrants, the survival rate and the drop-out rate, among others, thus intensifying the economic effects of drop-out on the actors in the higher education system.

METHODOLOGY

In order to fulfil the objective of this article, and to operationalise the proposed model (**Figure 1**), System Dynamics was used as the main modelling and simulation technique. This technique is borrowed from control theory, more specifically, from feedback systems and is distinguished by its ability to deal with nonlinearity, time delay, and multi-loop structures of complex and dynamic systems (Bala et al., 2017). Thus, System Dynamics allows us to analyse the structure of a system, the interactions between its elements and the behaviours derived from these interactions as a function of time (t) (Forrester, 2013).

That said, for the formal construction of the model, the procedure suggested by Bala et al. (2017) was followed, which consists of four stages. The first corresponded to the construction of the flows and levels diagram, understood as the physical structure of the system, in which the levels represent its condition for a defined t, and the flows are the changes resulting from the interaction of multiple variables that modify the initial condition of the system. This diagram, apart from representing the structure, reproduces the system of differential equations, thus achieving the simulation of the dynamic behaviour. The second structured the system of differential equations that represent the cause-effect relationships of the variables. The third established the parameters, assigning numerical values or equations with particular values to the variables of the model. These parameters allow the plausible behaviours of the system to be generated. The fourth, tested the consistency of the model, with the objective of verifying that the results obtained by the simulation of the model represented the behaviour of the system.

In the case of stage three, we used historical data from the National Higher Education Information System (SNIES), the System for the Prevention of Drop-out in Higher Education (SPADIES) and the MEN. In the case of SNIES, information related to undergraduate programmes (technical, technologist and professional) taught in rural areas was extracted, as well as the evolution of first semester enrolments in these programmes and the annual cost of enrolments. In total, the 20 training programmes with the highest number of enrolled students from rural areas for the year 2019 were included, being 25% technical training, 25% technological training and 50% vocational training (see **Supplementary Material Table S1**). From SPADIES, we extracted the number of students per training programme who accessed a credit with ICETEX (2021) in the medium and long-term modality and the survival rate of each of the training programmes; this rate represents the proportion of students in each semester who remain enrolled (Ministry of National Education, 2009). Finally, from the studies developed by the MEN, the impact of COVID-19 at the higher education level was determined. The period of observation of the data was from 2015 to 2020, whose history was crucial for the estimation of parameters and validation of the model proposed in this article in terms of structure and behaviour.

With the model and data, the model was run to assess the economic effects of rural student drop-out on higher education stakeholders. To this end, the simulations described in **Table 1** were carried out.

Finally, the computational work on the model and the simulations were implemented in Stella Architect Software version 1.9.5. The following model settings were taken into account: $t_i = 0$, $t_f = 18$, $\Delta t = 1$, units of t in academic periods and Euler as the selected integration method. The t_i represented year 2015 first semester and the t_f year 2024 first semester as well.

RESULTS

In accordance with the methodology, the following presents firstly the formal construction of the model, and secondly the results of the simulation scenarios.

Forrester Diagram and Mathematical Model

Based on the dynamic hypotheses (see **Figure 1**), the Forrester diagram and the mathematical model were designed considering the flow, level and auxiliary variables necessary to replicate the drop-out phenomenon (see **Supplementary Material S2**). With the design of the diagram and the base model presented below, the corresponding adaptations were made to run the simulations, since the training programmes in the sample have different numbers of academic periods that students must complete to graduate (see Guzmán et al., 2021b; Guzmán et al., 2021c; Guzmán et al., 2021d). Thus, the base model was divided into five subsystems.

Subsystem One

The first subsystem corresponded to the behaviour of enrolment, retention, dropout and graduation of rural students at the higher education level. This starts with first semester enrolment, which is affected by the number of available bachelor graduates in the catchment area of the HEI and the first semester enrolment rate. Subsequently, enrolled students must make a decision at the end of each academic period whether to continue their education or drop out, and this is repeated until the group of students

TABLE 1 | Computer simulations.

Code	Simulation
SIM-1	Baseline behaviour of the model with initial parameters
SIM-2	System behaviour in the absence of the COVID-19 pandemic
SIM-3	Consolidation of the public policy of tuition fee waivers in public HEIs as a result of the social crisis resulting from COVID-19

graduates, thus forming the group of graduates. The equations describing the behaviour of this subsystem are presented below. It should be noted that, for all subsystems, N symbolically represents the semester the student is studying in a specific t, and n the number of academic periods to be simulated.

$$B_t = (B_{t-1} + BRG - G)\,dt$$

$$EMN_t = [EMN_{t-1} + (EMN \times (TSN - ECOVID_D)) - (EMN \times (TDN + ECOVID_D))]\,dt$$

$$EDN_t = [EDN_{t-1} + (EMN \times (TDN + ECOVID_D))]\,dt$$

$$G_t = [G_{t-1} + (EMN \times TSN)]\,dt$$

$$TD_t = \sum_{t=0}^{n} EDN_t\,dt$$

The previous set of equations operates as long as the technical condition of non-negativity are found $ECOVID_D$, in other words, $ECOVID_D \geq 0$. For the case of FN and the development of the simulations, 0.01 was taken as the value resulting from the estimates of the Ministry of National Education.

$$ECOVID_{Dt}\begin{cases} ECOVID_D = 0\ \ dt & si\ ECOVID_D = 0 \\ ECOVID_D - FN\,dt & si\ ECOVID_D > 0 \end{cases}$$

On the other hand, by not considering academic periods prior to the observation period $EM1_t$, This is understood as the academic period in which incoming students join, so this is not defined in terms of EMN_t, but as presented below. It should be noted that, $EM1_t$ is directly affected by the absence or presence of the effect of COVID-19, it should be noted that negative values in the $ECOVID_A$ variables mean that the HEIs increased the number of students when comparing the years 2019 and 2020 so FN adds, otherwise, if positive, they denote a decrease in the number of students, so FN substracts.

$$EM1_t = [EM1_{t-1} + ENI - (EMN \times TSN) - (EMN \times TDN)]\,dt$$

$$ENI_t = \begin{cases} ENI_{t-1}\,dt & si\ ECOVID_A = 0 \\ [ENI_{t-1} - (ENI \times ECOVID_A)]dt & si\ ECOVID_A \neq 0 \end{cases}$$

$$ECOVID_{At} = \left\{ -\left(\frac{\sum EMN_{2020}}{\sum EMN_{2019}}\right) - 1 \right\} \pm FN\,dt$$

Subsystem Two

The second sub-system represented the enrolment, retention, dropout and graduation of rural students in one of the state programmes with respect to the financing of enrolment with educational credits. Recognising that each country has particular policies, a synthesis of the mathematical model that can be adjusted to different varieties of educational credits is presented, which, in the case of Colombia, are categorised as long and medium term.

$$EMNTC_t = [EMNTC_{t-1} + (EMNTC \times (TSN - ECOVID_D)) - (EMNTC \times (TDN + ECOVID_D))]\,dt$$

$$EDNTC_t = [EDNTC_t + (EMNTC \times (TDN + ECOVID_D))]\,dt$$

$$GTC_t = [GTC_t + (EMNTC \times TSN)]\,dt$$

$$TDTC_t = \sum_{t=0}^{n} EDNTC_t\,dt$$

As long as the provided technical conditions of non-negativity are found, $ECOVID_D \geq 0$.

$$ECOVID_{Dt}\begin{cases} ECOVID_D = 0\ \ dt & si\ ECOVID_D = 0 \\ ECOVID_D - FN\,dt & si\ ECOVID_D > 0 \end{cases}$$

Now, for the observation period $EM1TC_t$, as it does not take into account previous academic periods and this is the period in which new students join, it has been defined as follows.

$$EM1TC_t = [EM1TC_{t-1} + (EM1TC \times TTC) - (EMN \times TSN) - (EMN \times TDN)]\,dt$$

Subsystem Three

The third sub-system describes the economic effects of dropout for HEIs. It is divided into three sectors. The first sector corresponds to the opportunity cost for HEIs, where the higher the number of dropouts in the first academic terms, whether credit or non-credit students, the higher the opportunity cost. For the quantification of this cost a time lag was used, recognising that once a student drops out, it is in the next academic term that the financial impact will materialise. This is represented in the following set of equations.

$$CON_t = f\ (x_t,\ x_{t-\tau},\ t)\,dt; t \geq t_0$$

$$x = CON_{t-1} + (EDN \times MATN)$$

$$COT_t = \sum_{t=0}^{n} CON_t\,dt$$

The second sector corresponds to the benefits or additional income resulting from untimely graduation, these are only quantified when part of the student population attends more academic periods than those established by the training programme; for the purposes of this study, only two additional academic periods were considered, although the model is adjustable to as many periods as required. The equations for this sector are described below.

$$BON_t = [BON_{t-1} + (EGT \times MATN)]\,dt$$

$$BOT_t = \sum_{t=0}^{n} BON_t\, dt$$

The third sector of this subsystem quantifies the financial effects of drop-out for HEIs. In this case C_IES_t takes negative values, it means that for a specific t the unanticipated revenue from untimely graduation was greater than the associated cost of drop-out. This is expressed as follows.

$$C\_IES_t = [COT_t - BOT_t]\, dt$$

4.1.4 Subsystem Four

The fourth sub-system refers to the financial effects of drop-out for the student and his/her family. This represents the stranded cost which is the result of the cumulative value of tuition fees paid by dropouts, the interest generated by educational credits and the cost of untimely graduation. This is shown in the following set of equations.

$$CHN_t = \begin{cases} [(EDN_t \times MATN) + BON_t + INT_t]\, dt & T\_IES = 0 \\ 0 & T\_IES = 1 \end{cases}$$

$$INT_t = [(EDNTC_t \times MATN) \times Ti_t]\, dt$$

$$CHT_t = \sum_{t=0}^{n} CHN_t\, dt$$

Subsystem Five

The fifth sub-system represents the financial effects for the state. In this case, a portion of dropouts will not be able to cover the debts of their educational credits, and this portion is likely to increase due to the effects of COVID-19. Furthermore, in the case of public HEIs where the state bears the cost of tuition fees, drop-out represents an additional cost. This is described by the following set of equations.

$$CEN_t = \{[((EDNTC_t \times MATN) + INT_t) \times (Tnp + ECOVID_E)] + (EDN_t \times MATN \times T\_IES)\}dt$$

$$CET_t = \sum_{t=0}^{n} CEN_t\, dt$$

The above set of equations operates, as long as the provided technical conditions of non-negativity for $ECOVID_E \geq 0$, and binary assignment for the case of T_IES_t are found as follows

$$ECOVID_{Et} \begin{cases} ECOVID_E = 0\ dt & si\ ECOVID_E = 0 \\ ECOVID_E - FN\ dt & si\ ECOVID_E > 0 \end{cases}$$

$$T\_IES_t \begin{cases} T\_IES = 0 \\ T\_IES = 1 \end{cases}$$

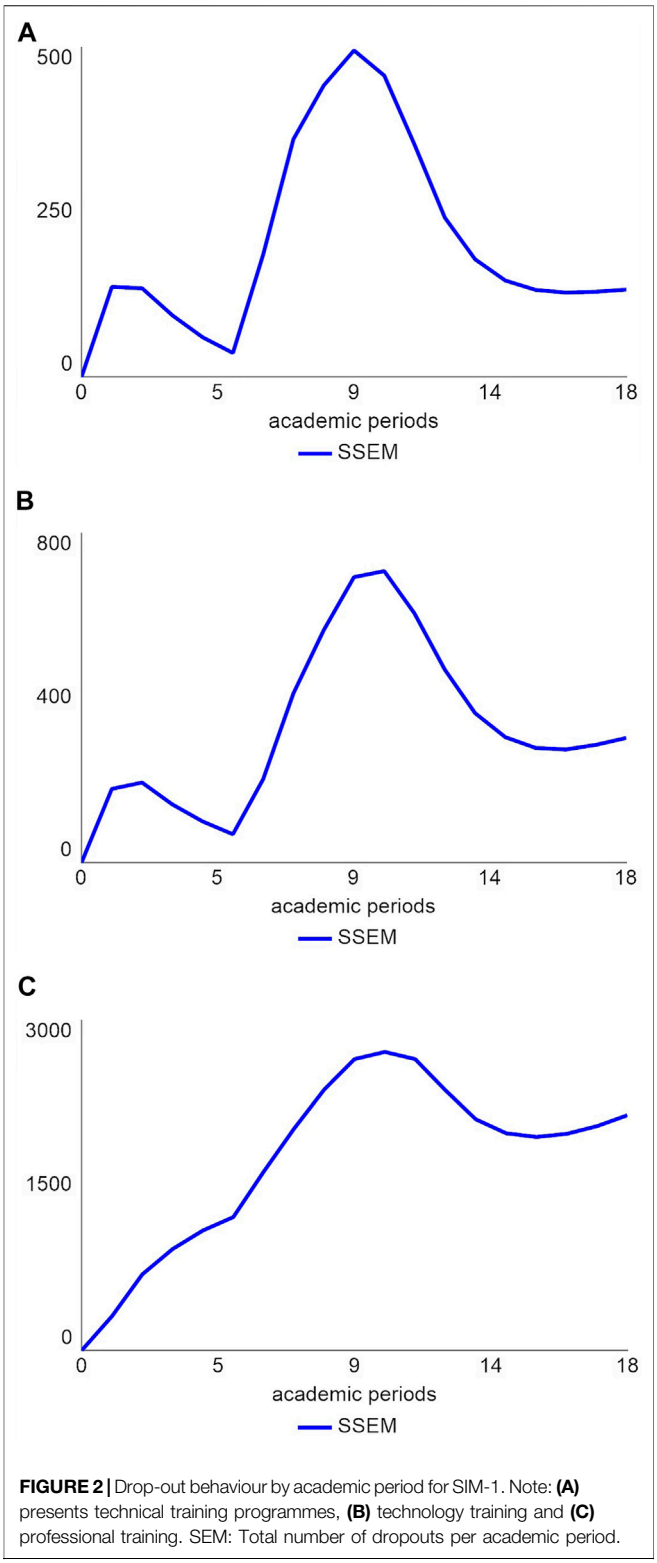

FIGURE 2 | Drop-out behaviour by academic period for SIM-1. Note: **(A)** presents technical training programmes, **(B)** technology training and **(C)** professional training. SEM: Total number of dropouts per academic period.

Operationalisation Results of the Model and Simulations

With regard to the simulations, in the case of SIM-1, which reflected the reference mode, as for example the behaviour of the system under the initial parameters, it was found that in the case of the technical training programmes from the second semester of 2019, 2019-2 ($t = 9$), and prior to COVID-19, there was a decrease in the number of students enrolled from 496 to 396 students for the period 2020-1 ($t = 10$) and 330 for 2020-2, according to the developed prospective scenario, the five

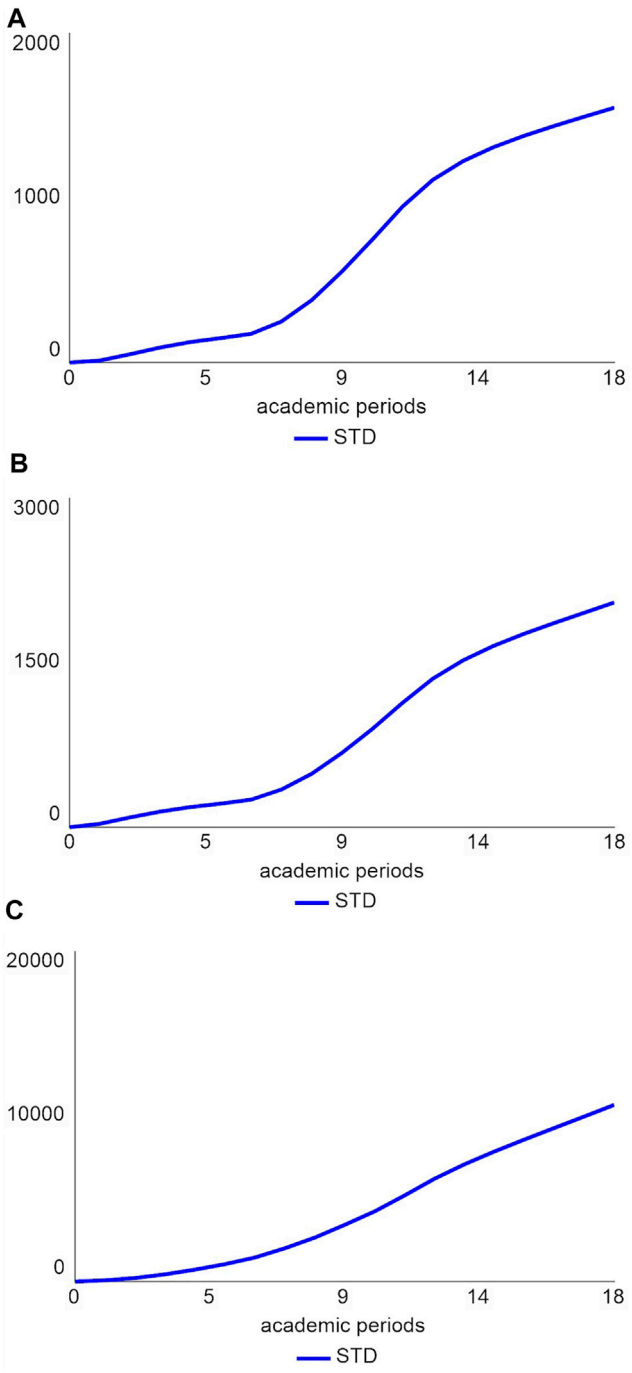

FIGURE 3 | Drop-out behaviour for SIM-1. Note: **(A)** presents technical training programmes, **(B)** technological training and **(C)** professional training. STD: Total number of dropouts per *t*.

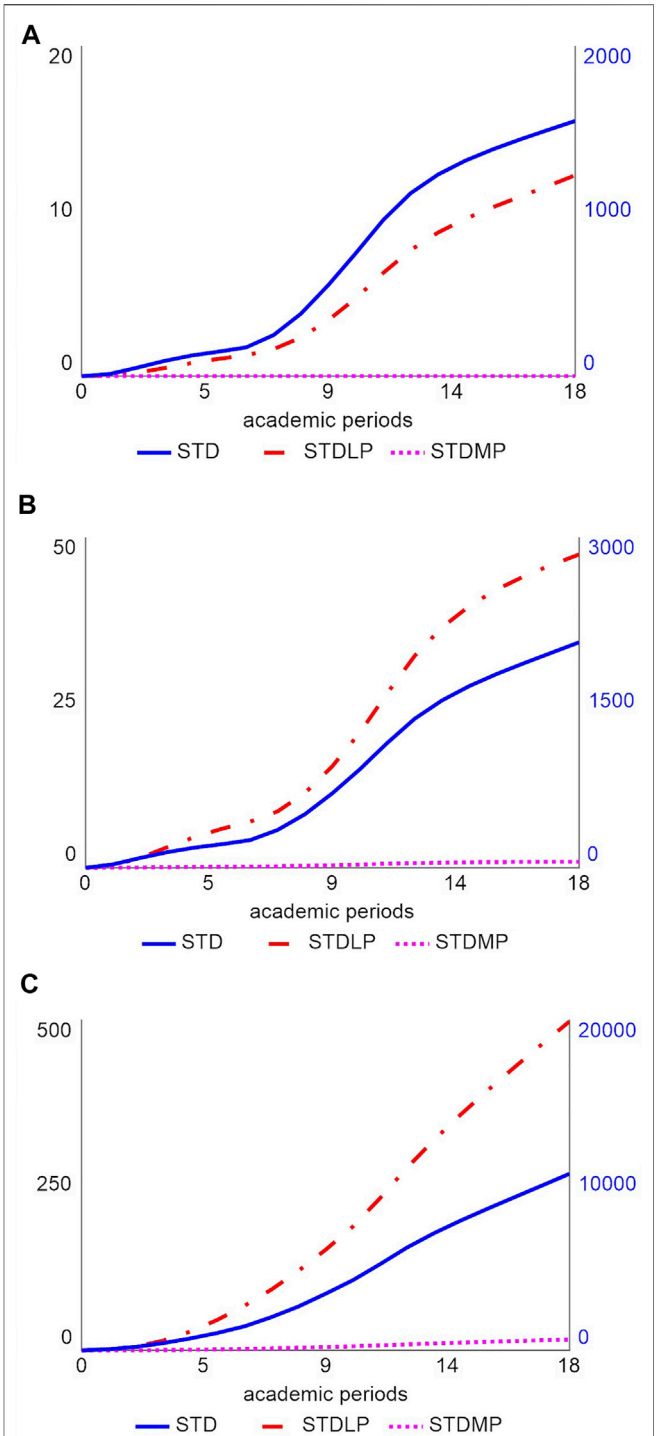

FIGURE 4 | Drop-out behaviour by type of academic credit for SIM-1. Note: **(A)** presents technical training programmes, **(B)** technological training and **(C)** professional training. STD: Total number of dropouts per *t*. STDLP: Total number of dropouts with long-term credits per *t*. STDMP: Total number of dropouts with medium-term credits per *t*.

training programmes in the sample are expected to have 312 students enrolled for the period 2024-1 ($t = 18$). In the case of technological and vocational training programmes, the decrease in students began with the onset of the pandemic. Thus, in the case of the former, 709 students were enrolled at $t = 10$ and 606 were enrolled at $t = 11$; in the case of the latter, 2,720 students were enrolled at $t = 10$ and $t = 11$ 2,650. Now in relation to the prospect, of the number of enrolments for the period 2024-1 for the technological programmes ($n = 5$) it was estimated that

there will be 303 students enrolled and for the vocational programmes ($n = 10$) 2,140. **Figure 2** shows the enrolment behaviour for the three types of training programmes. In addition, **Supplementary Material Figure S1** shows the enrolment behaviour for each of the academic periods by type of programme.

In terms of student drop-out rates for the technical, technological and vocational training programmes in the sample, before the start of the pandemic there were 747, 330 and 4,250 drop-outs respectively (see **Figure 3**), as a result of the effect of COVID-19, it was estimated that for the period 2024-1 ($t = 18$), 803 students enrolled in technical training programmes, 1,720 in technological training and 6,450 in vocational training will drop out, which represents an increase in the total number of dropouts of 7.4%, 421.12% and 151%, respectively. In the **Supplementary Material Figure S2** presents the drop-out behaviour for each of the academic periods by type of programme.

However, with regard to the number of students with academic credits who drop out, it is characterised by being low in comparison with the number of total dropouts from the training programmes under study, which can be explained to a large extent by the low rate of access to educational credits by the rural population. In this sense, the simulation for $t = 18$, allowed to establish that for technical training programmes $12.2 \approx 13$ students will have dropped out with educational credits, technological $48.4 \approx 49$ and professional $515.4 \approx 516$. **Figure 4** shows the comparison between the number of drop-outs from training programmes and those who accessed an academic credit.

Regarding the economic effects of drop-out for the actors in the education system, the simulation showed that for the five technical training programmes for the period 2019-2 ($t = 9$), it means that before the start of the pandemic, they had a drop-out cost of 494,000,000 Colombian pesos (USD 130,768.37), students and their families had a stranded cost of 694,000,000 Colombian pesos (USD 183,711.03), and the state had a non-payment cost of nearly 69,300,000 Colombian pesos (USD 18,344.63). It was also estimated that by the year 2024-1 ($t = 18$) the total cost of drop-out for the training programmes will be 7,590,000,000,000 Colombian pesos (USD 2,009,173.95), for the family and the student 7,560,000,000,000 Colombian pesos (USD 2,001,232.55), and for the State 1,380,000,000 Colombian pesos (USD 365,304.35).

In the case of the five technological training programmes, the drop-out costs for t = 9 were 1,280,000,000 Colombian pesos (USD 338,833.02), for the students and their families 1,600,000,000 pesos (USD 423,541.28), and for the state 128,000,000 Colombian pesos (USD 33,883.30). In turn, for this same type of programme for $t = 18$ it was calculated that the cost of the drop-out phenomenon will be 13,500,000,000 Colombian pesos (USD 3,573,629.55), for students and families 13,600,000,000 Colombian pesos (USD 3,600,100.88), and for the State 2,470,000,000 million Colombian pesos (USD 2,470,000,000 million).

For the ten professional training programmes, the drop-out costs for $t = 9$ were 1,850,000,000,000 pesos (USD 489,719.60), for students and their families 2,750,000,000 Colombian pesos (USD 727,961.58), and for the state 141,000,000 (USD 37,324.58). From the simulation for $t = 18$ it was determined that the drop-out costs will be close to 25,000,000,000,000 Colombian pesos

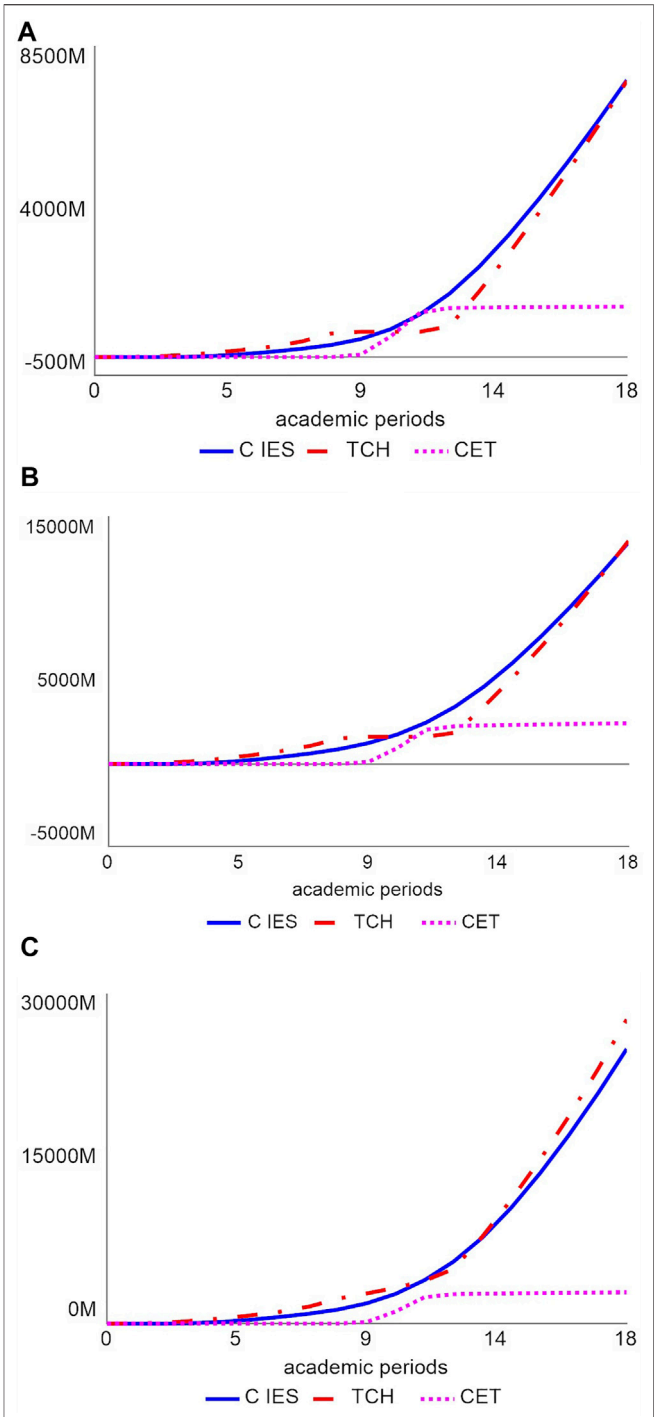

FIGURE 5 | Behaviour of the economic effects of drop-out for SIM-1. Note: **(A)** presents technical training programmes, (B) technological training and **(C)** professional training. C IES: Total cost for the training programmes under study per *t*. THC: Stranded cost for the family per *t*. CET: Total cost for the State per *t*.

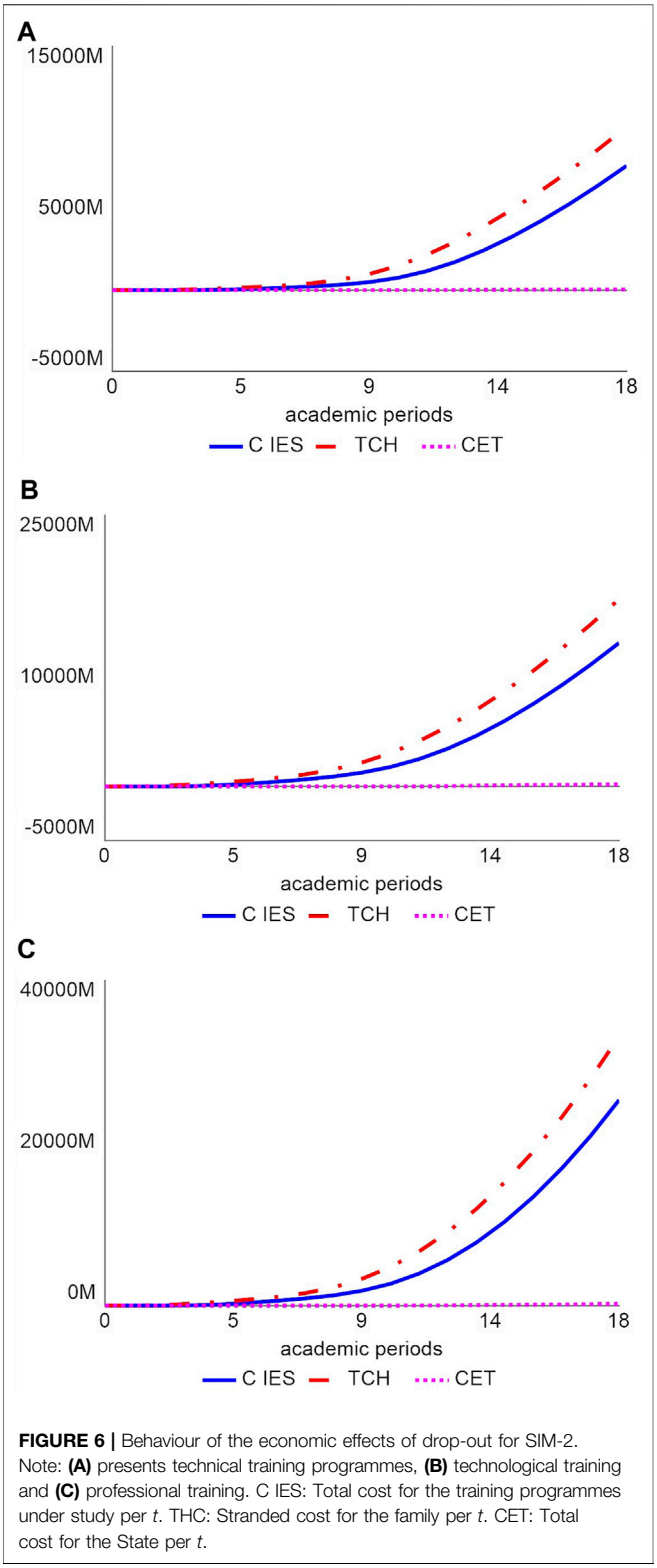

FIGURE 6 | Behaviour of the economic effects of drop-out for SIM-2. Note: **(A)** presents technical training programmes, **(B)** technological training and **(C)** professional training. C IES: Total cost for the training programmes under study per *t*. THC: Stranded cost for the family per *t*. CET: Total cost for the State per *t*.

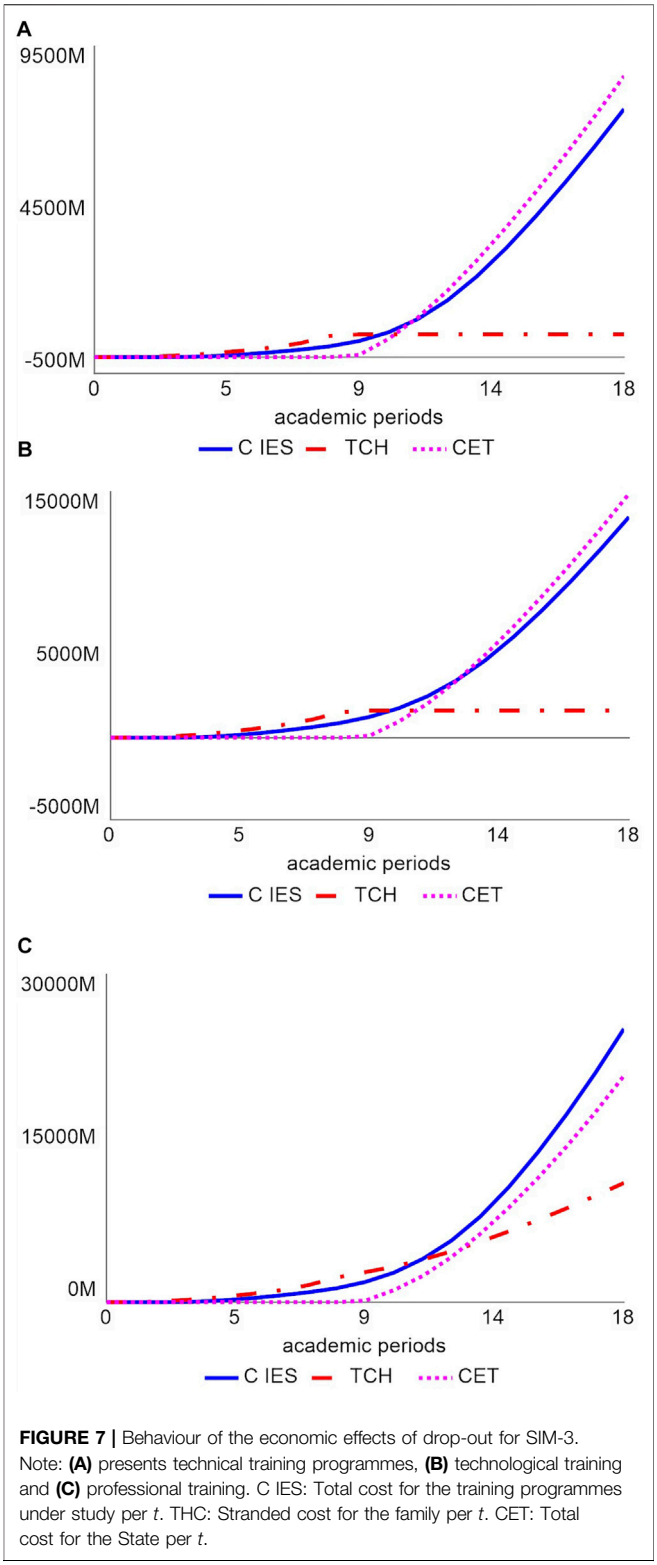

FIGURE 7 | Behaviour of the economic effects of drop-out for SIM-3. Note: **(A)** presents technical training programmes, **(B)** technological training and **(C)** professional training. C IES: Total cost for the training programmes under study per *t*. THC: Stranded cost for the family per *t*. CET: Total cost for the State per *t*.

(USD 6,617,832.50) for the professional training programmes, 27,700,000,000 Colombian pesos (USD 7,332,558.41) for the students and their families, and 2,850,000,000 Colombian pesos (USD 754,432.91) for the state. **Figure 5** shows the behaviour of the system in terms of economic effects. It should be noted that for the interval from $t = 9$ to $t = 11$ the Colombian state implemented the tuition fee exemption plan in

public HEIs (called "*Matricula Cero*"), hence for each type of programme there is an increase in the cost to the state.

SIM-2 assessed the possible economic effects of drop-out in the absence of COVID-19 and changes in the state's higher education access policies; firstly, it was determined that the number of drop-outs for the training programmes in the sample would increase, since in the absence of the pandemic there would not be a decrease in enrolments. Thus, for the five technical training programmes, the number of dropouts for $t = 18$ de 1,680; for the five technological training programmes it would be 2,140; and for the ten vocational training programmes it would be 10,900. That stated, in relation to the results obtained in SIM-1, the cost for HEIs would be similar, given that the additional income of HEIs from untimely graduation also increases. Thus, for technical training programmes, for $t = 18$, this cost would be 7,650,000,000 Colombian pesos (USD 2,030,254.78), for technological programmes it would be 13,200,000,000 Colombian pesos (USD 3,503,184.71) and for university training programmes it would be 25,300,000,000 Colombian pesos (USD 6,714,437.37).

On the other hand, in the absence of tuition fee exemption policies in public HEIs, the cost of drop-out should be assumed by the student and his or her family. Given the above for $t = 18$ the stranded cost for students and their families in technical programmes would be 10,000,000,000 Colombian pesos (USD 2,653,927.81), in technological programmes it would be 17,300,000,000 Colombian pesos (USD 4,591,295.12) and in vocational programmes it would be 33,100,000,000 Colombian pesos (USD 8,784,501.06). **Figure 6** shows the economic effects for actors at the higher education level.

Finally, in relation to SIM-3, this sought to evaluate the economic effects of the new policies of access to higher education implemented in the framework of COVID-19, which for the Colombian case has included the financing of the academic periods of students in public universities by generating the exemption of tuition fees. Thus in this simulation for the periods from $t = 13$ to $t = 18$ this free policy was extended. The results of this simulation show that the implementation of such policies changes the stranded cost from the student and his or her family to the state. In this sense, for the case of the technical training programmes in the sample, the cost of drop-out for the State would be 8,590,000,000,000 Colombian pesos (USD 2,279,723.99), in technological training it would be 14,900,000,000 Colombian pesos (USD 3,954,352.44) and in vocational training it would be 20,700,000,000,000 Colombian pesos (USD 5,493,630.57); for the student and his/her family the stranded cost would be 694,000,000,000 Colombian pesos (USD 184,182.59), 1,660,000,000,000 Colombian pesos (USD 440,552.02) and 10,900,000,000,000 Colombian pesos (USD 2,892,781.32), respectively. **Figure 7** shows the results of the simulation in terms of costs for the actors in the education system.

5 DISCUSSION AND CONCLUSION

As presented in the results section, the objective of this article was achieved, which was to model the economic effects of rural student drop-out at the higher education level for students and families, HEIs and the state, based on public policies for access to higher education, in the pandemic and post-pandemic scenario. However, it is necessary to recognise that the present study raises a new perspective on the phenomenon of drop-out and COVID-19, which had not been widely explored before this article, such as the economic effects for higher education actors, thus complementing previous studies that have analysed this relationship, such as those developed by Teuber et al. (2021), Cruz et al. (2020), Delnoij et al. (2021), Alyoussef (2021) and Cameron-Standerford et al. (2020).

The development of the model for the evaluation of the economic effects of drop-out was based on an integrative vision, distinguishing it from previous models that analysed these effects individually for each actor in the system, such as the works by World Bank, (2020), Bernal (2018), Barragán and Rodríguez (2015). On the other hand, this model makes it possible to link the consequences of COVID-19 on the rates of access to higher education, survival, drop-out and non-payment of educational credits. In addition to the above, the proposed model, based on System Dynamics, made it possible to understand and predict the economic effects of drop-out in terms of time t, brought about by the implementation, modification and elimination of public policies for access to higher education for the actors at this level of education. Although the article focused on rural areas, because of the intrinsic value of education for the development of these areas, especially in developing countries (Herbaut and Geven, 2020; Guzmán et al., 2021a; United Nations, 2021), the model is useful for any student population, HEI or state, as it seeks to represent the behaviour of the education level system.

With regard to the economic effects of drop-out in rural populations, it became evident that prior to the pandemic, in the case of Colombia, and more specifically of the training programmes in the sample, students and their families assumed a considerably high stranded cost, especially when, on average and according to UNDP statistics (2021), 50% of this population lived in monetary poverty and 27.9% in extreme poverty, with monthly incomes of less than 199,828 pesos (USD 53.17). However, during the pandemic and with the prospective scenarios after the pandemic, the financial relief achieved by public policies of temporary tuition fee waivers is insufficient, given that by 2024 the stranded cost for students and their families is estimated to be higher than the cost assumed by HEIs and the state. In the case of HEIs, COVID-19 has represented an exponential increase in opportunity cost in rural areas. Consequently, the pandemic has the singularity of directly affecting the development of the substantive functions of training programmes, due to the decrease in first-time enrolments and the increase in drop-out rates, which is in line with (Basilaia and Kvavadze, 2020). For the State, prior to the pandemic, the cost incurred was limited to non-payment of loans, however, the student population of the sampled programmes does not typically make use of educational loans so the non-payment rate may be high and not have a major impact on the credit-based student tuition funding programmes.

In the scenario in which COVID-19 had not occurred and affected the level of education in rural areas, the economic effects of drop-out would have intensified for students and their families, as well as for HEIs, because enrolment and its rates would have remained high for training programmes. Finally, for the simulation of the implementation of policies not based on educational credit but on tuition fees, the cost for the student and his or her family would be significantly reduced, as it would be assumed by the state.

Consequently, this article highlights the shortcomings of public policies on access to higher education for the rural student population, both in the pandemic and post-pandemic scenarios, as they do not have the capacity to mitigate the drop-out phenomenon, which contrasts with the results of (Mayer et al., 2015). For this reason, it is necessary to continue delving into the reasons why rural students drop-out, since socio-economic variables related to tuition fees do not fully explain the dropping out and high drop-out rates among this student population, and the policies developed by Western countries are insufficient to transmit the intrinsic and extrinsic benefits of the educational level, as stated by Guzmán et al (2021b).

Thus, the limitations of the study, such as the sample size of the training programmes and policies analysed, must be acknowledged. Finally, the academic community is invited to consider the model as a reference, to adjust and adapt it to learn about other economic effects on diverse student populations. On the other hand, decision-makers in the development of public policies for access, retention and timely graduation of higher education students in rural areas are urged to foresee the effects that the simulations presented with the proposed model will have on the different actors at the educational level.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://doi.org/10.6084/m9.figshare.16944235.v1.

AUTHOR CONTRIBUTIONS

AGR and SBM contributed to conception and design of the study. AGR organized the database. AGR performed quantitative and qualitative analysis. AGR and SBM wrote the first draft of the manuscript. AGR, SBM, and FC-V reviewed and edited. SBM and FC-V supervised both the development of the research and the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2021.812114/full#supplementary-material

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