A novel approach for exploring the trade-offs between several features of students' well-being

González-Gallardo, S.[1], Henriques, C. O.[2,3], Marcenaro-Gutierrez, O.D.[4], Luque, M.[1,*]

[1] Department of Applied Economics (Mathematics), Universidad de Málaga, C/ Ejido, 6. 29071 - Malaga, Spain.

[2] Polytechnic Institute of Coimbra, ISCAC Business School, Quinta Agrícola, Bencanta, 3040-316 Coimbra, Portugal, chenriques@iscac.pt

[3] INESC Coimbra – DEEC, University of Coimbra, Polo 2, 3030-290 Coimbra, Portugal

[4] Department of Applied Economics (Statistics and Econometrics), Universidad de Málaga, C/ Ejido, 6. 29071 - Malaga, Spain

Abstract

We propose a novel approach to explore the trade-offs between four features of students' well-being (anxiety, motivation, sense of belonging and bullying). On the one hand, a multiobjective interval problem is formulated by considering these distinct components of well-being as objective functions, being then instantiated with confidence intervals obtained from distinct econometric estimations. Then, the problem is solved through the use of a reference point approach that allows accounting for the decision-maker's preferences by considering a set of weight vectors that can be used to express his/her preferences regarding the importance that should be given to each objective function. The results provide information on how the improvement of one objective might affect the remaining objectives. Furthermore, the student's profile corresponding to each scrutinized solution is also made available. Overall, the results claim that bullying is the most affected objective, highlighting the need to foster anti-bullying education policies in Spanish schools, according to PISA 2015 data. Finally, some educational polices are suggested in order to enhance students' well-being.

Keywords: Students' well-being; Multiple objective programming; Econometric analysis; Interval programming

*Corresponding author: Mariano Luque (mluque@uma.es). Universidad de Málaga, C/Ejido, 6, 29071, Málaga, Spain. Tfn: 952131173.

1. Introduction

Education policy should not only address students' academic attainment since there is evidence that programmes that promote students' broader well-being and development also benefit their academic learning (Bonell et al. 2014). In fact, schools in countries with better academic attainment such as Finland, Sweden, Australia, and Singapore place a great emphasis on students' overall development, and social and emotional learning, suggesting that academic and broader development is not a zero-sum game (Humphrey, 2013).

Furthermore, it has also been broadly acknowledged that the learning process is embedded in emotional states (American College Health Association, 2012). Hence, schools should also manage students' well-being and stress because these two features affect students' outcomes at school as well as their ability to thrive in their later life.

In order to foster students' well-being a suitable investment in the acquisition of non-cognitive and work associated competences is required in the present. In fact, there is evidence that shows that an effective labour force does not simply involve cognitive skills obtained from academic learning. As education policy is a key factor in economic growth (Barro, 2001), its enhancement requires non-cognitive skills, such as resilience and team working skills (Heckman et al., 2006). Furthermore, without policies that specifically address concerns with the development of present students' capabilities, it is quite likely that these future adults will not be fulfilled in terms of well-being, potentially affecting their productivity as workers (Warr, 1999). Therefore, the necessity of sustaining students' well-being has been progressively capturing the attention of countries' educational policymakers (Matthews et al., 2015).

In order to assess students' well-being, it is necessary to recognize that adolescents usually have different priorities and as such the Program for International Students Assessment (PISA) has been specifically designed to address the population of 15-year-old students. PISA is a study designed to evaluate education systems worldwide every three years – from 2000 – by assessing the 15-year-olds' competencies (knowledge, understanding and fundamental skills) to participate in today's society.

It is broadly acknowledged that adult's well-being relies on a multitude of features (sometimes conflicting) that are possibly interwoven with each other (Huebner and Dew, 1993; Huebner and Gilman, 2002; Coad and Binder, 2014; Hsieh, 2018; among others). In this sense, like adults, students' well-being is intrinsically a multidimensional concept, which encompasses four distinct axes of evaluation (Kern et al., 2015; OECD, 2017): psychological, social, cognitive and physical.

Hence, from what was previously established the concept of well-being is intricate and requires the use of a multitude of indicators from distinct domains to measure it (Borgonovi and Pál, 2016).

Consequently, in this study we employ multiobjective programming tools, which are particularly suitable in our case since they allow incorporating the intrinsic multidimensional nature of the problems under analysis. Despite of their usefulness, this type of methods has rarely been used with qualitative variables to tackle the distinct aspects of students' well-being (Marcenaro-Gutierrez et al., 2020). An additional novelty of this study resides on the combination of both multiobjective interval programming techniques and econometric models, enabling to gain further insights and results that classical econometric tools are not able to offer, concretely the obtention of "efficient compromise solutions" under different scenarios herein given as intervals. In line with recent operational research works (Stefanakis and Doumpos, 2021, González-Fernández et al., 2020; Lombardi Netto et al., 2020), this paper shows that multiobjective optimization programming, in our case the multiobjective interval programming approach, is very suitable for obtaining the optimum of real problems, in particular, considering different scenarios.

To sum-up, we assess the Spanish students' well-being through a two-step framework. At first, we develop our analysis through econometric estimates to establish the correlation between the different aspects of students' well-being (anxiety, motivation, sense of belonging and bullying) and a set of contextual aspects. Specifically, we consider the sociodemographic features of students, their abilities with the information and communication technologies (ICTs), internet, and learning hours, among others. Subsequently, we use multiobjective interval programming techniques to explore different trade-offs (a trade-off describes the situation where an improvement of one of the aspects under evaluation is associated with the worsening of, at least, one of the others) and compromises across these aspects of students' well-being which are viewed as objective functions. In this context, the confidence intervals obtained with the econometric estimates are then used to instantiate the coefficients of the objective functions.

Our findings allow obtaining the profile of the "most satisfied" student, according to the well-being aspects under evaluation. Then, a reference point approach adjusted to our interval model is employed to evaluate the trade-offs between the several aspects that might influence students' well-being and generate solutions that achieve at the same time optimal compromise values for the indicators considered according to the preferences of the decision-maker. The information thus obtained can help shape Educational policies in Spain, allowing to anticipate the impacts that these can have on the measures of well-being herein contemplated. Somehow, this analysis covers the need of studies with unconventional quantitative techniques that help shed light on how to improve students' well-being.

The rest of the paper is organized as follows. In Section 2 a literature review on students' well-being has been performed. The data used and the econometric analysis are described in Section 3. Section 4 further explains the formulation of the interval multiobjective problem proposed. In Section 5, the underpinning assumptions and the solution approach followed are presented. Section 6 provides the analysis and description of different illustrative results. Finally, in the last section, some conclusions are drawn, and some policy implications are suggested.

2. Literature review

Despite the multidimensional nature of students' well-being, the literature on this topic has been mainly focused on specific features without comprehending a holistic assessment. In particular, the American College Health Association (2012) studied the way stress and anxiety affect students' academic achievement and how bullying and discrimination have an impact on students' mental health. This topic is particularly relevant since schools are facing recurring acts of violence, leading to a poor school environment, possibly influencing students' dropout rates and academic outcomes. In this vein, Strøm et al. (2013) conducted a multilevel analysis to estimate the individual and contextual influence of students' school environment on academic performance. Their findings suggest that students attending schools with higher levels of bullying had worse academic results. In addition, with regard to bullying, Knaappila et al. (2018) studied the socioeconomic trends in school bullying across Finish adolescents from 2000 to 2015, having found that bullying and suffering bullying were related with socioeconomic difficulties.

More recently, Li et al. (2019) studied the relationship between anxiety, depression, gender, obesity and internet addition in Chinese adolescents, having concluded that anxiety was correlated with internet addition and boys had a higher level of addiction than girls.

Parhiala et al. (2018) studied how students' motivation affected well-being and academic results, having concluded that students with low levels of well-being and motivation were those who underperformed in math and reading. However, high levels of overall well-being were not necessarily reached with high levels of motivation and academic performance. Additionally, it has also been established that learning difficulties regarding subjects such as mathematics or reading are associated with a negative impact on students' motivation (Jõgi et al., 2015).

Recently, Korpershoek et al. (2019) also assessed the relationship between gender and cultural differences in school motivation. Overall, they managed to conclude that, in general, in all cultural groups, girls had slightly higher scores on mastery motivation and social motivation, whereas boys had slightly higher scores on performance motivation.

Ryan and Deci (2000) addressed the sense of belonging, which is another aspect that significantly influences students' well-being and motivation. With this regard, Chiu et al. (2016) studied whether students' sense of belonging at schools differed across different attributes of countries, namely families, school type, teachers, or students. This study has been done through a multilevel analysis of survey and test data from 15-years-old students in 41 countries. These authors concluded that more hierarchical cultures usually had fainter relations with teachers, leading to lower levels of sense of belonging. Furthermore, students in countries with more homogeneous socioeconomic status within the same school also had a higher sense of belonging.

From the review conducted it can be seen that there is a lack of literature addressing the trade-offs between the several aspects that might influence students' well-being. Therefore, we are aimed at filling this gap in the literature by proposing a novel approach that allows assessing the trade-offs among anxiety, motivation, sense of belonging and bullying at school through the joint combination of econometric and interval programming methodologies.

3. Econometrics analysis

3.1. Data

The data used in this paper are obtained from PISA 2015, which offers information on a wide range of personal and academic characteristics of students. This assessment has addressed approximately 540.000 15-year-old students from 72 countries.

The academic assessment is made through tests, which have a mixture of multiple-choice questions and questions requiring students to construct their responses. In these tests, students answered questions about three different competences (sciences, mathematics, and reading). Furthermore, 15-year-old students completed a background questionnaire that sought information about students, their homes and school learning experiences. In some countries, as in the case of Spain, the pupils answered two more questionnaires: the first one related to Information and Communication Technologies (ICTs) and the second one related to students' well-being. Based on these latter questionnaires, PISA provides four indexes of well-being related to anxiety, motivation, sense of belonging and bullying at school. We replicate these indexes through factor analysis and obtain them for the extended sample of Spain.

The first index (index of anxiety) is build based on five questions: "I often worry that it will be difficult for me taking a test; I worry that I will get poor <grades> at school; Even if I am well prepared for a test I feel very anxious; I get very tense when I study for a test; I get nervous when I don't know how to solve a task at school". The construction of the second one (index of motivation) is based on the following questions: "I want top grades in most or all of my courses; I want to be able to select from among the best opportunities available when I graduate; I want to be the best, whatever I do; I see myself as an ambitious person; I want to be one of the best students in my class". The index of sense of belonging is build based on the following six questions: "I feel like an outsider (or left out of things) at school; I make friends easily at school; I feel like I belong at school; I feel awkward and out of place in my school; Other students seem to like me; I feel lonely at school". The construction of the last index (index of bullying) is based on the following questions: "Other students left me out of things on purpose; Other students made fun of me; I was threatened by other students; Other students took away or destroyed things that belonged to me; I got hit or pushed around by other students".

Specifically, 32,330 students from 990 schools in Spain performed this assessment. We excluded from our analysis observations on any respondent who was enrolled in a private school, considering only students enrolled in semi-private and public schools. Besides, we only consider non-repeater students, to the extent that repeaters will be in lower grades. The sample was further reduced due to missing data in the variables under scrutiny. Therefore, the regressions are finally based on a sample of 17,128 observations.

The description of the variables used in our models (the explanatory variables) and the corresponding descriptive statistics are displayed in the appendix (Tables A1 and A2, respectively). After analyzing the data, we can establish that from the sample of schools selected, 30.5% are semi-private schools, whereas 69.5% are public schools. The proportion of students of both genders and the periods of birth are balanced. On average, Spanish students use internet three hours per day outside school, start using digital devices when they are seven years old and internet when they are eight years old. Moreover, they spend about four and three hours per week studying math and reading, respectively.

3.2. Econometric estimates

Each index (anxiety, sense of belonging, motivation, and bullying) has been regressed considering the set of explanatory variables presented in Table A1 (see the appendix). The coefficients are estimated using ordinary least square (OLS). The idea behind this estimator is to minimize the so-called statistical noise as much as possible. If the students are denoted by *"s"* and the indexes by *"j"*, the model can be represented by the following equations:

$$W^j(s) \ = \hat{\alpha}^j + \ \hat{\beta}_1^j escs(s) + \ \hat{\beta}_2^j semiprivate(s) + \cdots + \ \hat{\beta}_{11}^j hours_{reading}(s) + \epsilon^j(s)$$
$$j = 1, 2, 3, 4 \qquad s = 1, \ldots, n$$

where $W^j(s)$ is the index of well-being j ($j = 1, 2, 3, 4$) of student s; $escs(s), semiprivate(s), \ldots, hours\_reading(s)$ are the set of explanatory variables (presented in Section 3.1); $\epsilon^j(s)$ is the error term; $\boldsymbol{\hat{\beta}^j}$ is the vector of coefficients and $\boldsymbol{\hat{\alpha}^j}$ is a constant. In this way, we are assuming that each index of well-being is affected by random factors, which are normally distributed and unobservable.

Table 1 shows the lower and upper bounds of the estimated coefficients on the explanatory variables (significant at 10%, 5%, and 1%, respectively). Those coefficients which are not significant are reported as "0". The lower and upper bounds of the coefficients match with the confident interval at 95% obtained from the OLS estimations.

In what concerns the anxiety index, we can observe that the socioeconomic index is negatively associated with it, corroborating the idea that students with a higher socioeconomic status tend to show lower levels of anxiety. On the other hand, students who were born in October, November or December have a lower level of anxiety than those who were born in January, February or March. Furthermore, our findings are consistent with the ones obtained in Mann and Walshaw (2019) and Bieg et al. (2015), according to which girls show a higher level of anxiety than boys. Usually, girls tend to feel more responsible than boys and, therefore, studying and doing well causes them more anxiety. The use of ICTs increases the anxiety index levels, suggesting that using internet outside school for longer periods is associated with higher levels of anxiety (Li et al., 2019; Stavropoulos et al. 2017). Finally, spending more time studying is related with more anxiety (a higher responsibility for maintaining higher scores is a possible reason for obtaining this association).

Table 1. Lower and upper bounds of the coefficients.

Variables		Well-being indexes							
		Anxiety index		Motivation index		Sense of belonging index		Bullying index	
		Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound	Lower bound	Upper bound
Escs	x_1	-0.0799	-0.0455	0.0872	0.1199	0.0012	0.0334	0	0
Semi-private	x_2	0	0	0	0	0.0168	0.1191	0.0330	0.1362
Period two	x_3	0	0	0	0	-0.0023	0.1013	0	0
Period three	x_4	0	0	0	0	0.0544	0.1550	0	0
Period four	x_5	-0.0055	0.0913	0	0	0.0006	0.1123	0	0
Girls	x_6	0.2946	0.3600	-0.1131	-0.0509	0	0	-0.1737	-0.1001
Internet outside school	x_7	-0.0011	0.0134	-0.0188	-0.0057	0.0026	0.0199	0.0051	0.0221
Age at use digital dispenses	x_8	0.0101	0.0247	-0.0229	-0.0069	0	0	0	0
Age at use internet	x_9	-0.0011	0.0146	0	0	0	0	0	0
Hours of math	x_{10}	0.0136	0.0289	0.0039	0.0164	0.0016	0.0172	0	0
Hours of reading	x_{11}	0.0000	0.0173	0	0	0	0	0.0009	0.0187
Constant		-0.5681	-0.4403	0.3164	0.4801	-0.1618	0.0408	-0.1787	0.0347
Observations		17,128	17,128	17,128	17,128	17,128	17,128	17,128	17,128
R-squared		0.0825	0.0825	0.0334	0.0334	0.0061	0.0061	0.0111	0.0111

With regard to the estimation of the index of motivation, it is possible to perceive that students with a higher level of socioeconomic status have higher levels of motivation. In terms of gender, boys seem to be more motivated than girls. Our findings are supported by the results obtained in other studies (see e.g. Dilshad et al., 2019 and Akib et al., 2018). Furthermore, using internet outside school during longer periods is associated with lower levels of motivation to study. These results are supported by Demir and Kutlu (2008), which have demonstrated that internet addiction has a negative effect on the academic motivation of students. Finally, students who spend more hours studying mathematics, usually have more motivation. In the same vein, Parhiala et al. (2018) claim that students with lower levels of motivation do not obtain good results in mathematics and reading.

In terms of the sense of belonging, like in other studies (see e.g. Ostrove and Long, 2007), our findings suggest that students with a higher socioeconomic status have a positive association with the feeling of sense of belonging. In addition, students enrolled in semi-private schools have a higher sense of belonging than those enrolled in public schools. Focusing on the term of birth, we can perceive that students who were born from April to December have a higher sense of belonging than those who were born in January, February or March. Regarding the use of ICTs, our findings suggest that the number of hours using internet outside school is positively correlated with the estimation of this index, being consistent with the results obtained in the study conducted by Bannon et al. (2015). Finally, we were able to conclude that spending more time studying math is positively associated with the sense of belonging.

In what concerns bullying, the results show that there are more victims of bullying in semi-private schools than in public schools. The results of our estimations show that, as for e.g. Smith et al. (2019) have reported, boys suffer more bullying than girls.

Additionally, students who spend more hours using internet outside schools are associated with a higher bullying index. This can be explained by the increase of the phenomenon of cyberbullying. Finally, our estimations established a positive association between students who spend more time reading and the bullying suffered by these students.

4. The multiobjective interval model

In order to formulate the multiobjective interval problem, we have used the confident intervals (at 95%) of the coefficients computed from each regression conducted for the four objective functions, i.e. the anxiety index, the motivation index, the sense of belonging index and the bullying index (see Table 1). The objective functions thus obtained are the following:

Anxiety index $Min\ Z_1 = [-0.0799, -0.0455]x_1 + \cdots + [0.0136, 0.0289]x_{10} + [0.0000, 0.0173]x_{11} + [-0.5681, 0.4403]$

Motivation index $Max\ Z_2 = [0.0872, 0.1199]x_1 + \cdots + [0.0039, 0.0164]x_{10} + 0x_{11} + [0.3164, 0.4501]$

Sense of belonging index $Max\ Z_3 = [0.0012, 0.0334]x_1 + \cdots + [0.0016, 0.0172]x_{10} + 0x_{11} + [-0.1618, 0.0408]$

Bullying index $Min\ Z_4 = 0x_1 + [0.0330, 01362]x_2 + \cdots + [0.0009, 0.0187]x_{11} + [-0.1787, 0.0347]$

An additional set of technical constraints has also been considered both for the sake of consistency and with the purpose of obtaining realistic results. For example, the constraint related to the variables referring to the period of birth (binary variables) cannot take a value higher than one, meaning that each student can only be born in a single period, leading to the following constraint: $x_3 + x_4 + x_5 \leq 1$ $(C1)$. Other constraints have also been defined in order to consider the association between the explanatory variables. With this regard, we provide an example for illustrative purposes.

The relation between the socioeconomic index (x_1), gender (x_2) and the number of hours of internet use outside school (x_7) is given by:

$$x_7 = a + bx_1 + cx_2$$

Where the confident intervals (at 95%) are $a = [a^L, a^U] = [3.0638, 3.2321]$, $b = [b^L, b^U] = [-0.2411, -0.1317]$ and $c = [c^L, c^U] = [0.2487, 0.4592]$
which implies:

$$a^L + b^L x_1 + c^L x_2 \leq x_7 \leq a^U + b^U x_1 + c^U x_2$$

Therefore, the following constraints are obtained:

$$x_7 + 0.2411x_1 - 0.2487x_2 - 3.0638 \geq 0 \qquad (C2)$$

$$x_7 + 0.1317x_1 - 0.4521x_2 - 3.2321 \leq 0 \qquad (C3)$$

Following an analogous procedure, we obtain the remaining set of constraints.

The association between the socioeconomic index (x_1), gender (x_2) and the starting age for using digital devices (x_8) is given as:

$$x_8 + 0.3532x_1 - 0.4979x_2 - 6.8397 \geq 0 \qquad (C4)$$

$$x_8 + 0.2445x_1 - 0.7577x_2 - 7.064 \leq 0 \qquad (C5)$$

The relation between the socioeconomic index (x_1), gender (x_2) and the starting age for using internet (x_9) is obtained as follows:

$$x_9 + 0.3941x_1 - 0.3042x_2 - 8.2326 \geq 0 \qquad (C6)$$

$$x_9 + 0.3013x_1 - 0.5275x_2 - 8.3716 \leq 0 \qquad (C7)$$

The association between the socioeconomic index (x_1), gender (x_2) and the number of hours dedicated to studying math (x_{10}) is established in the followings equations (in this case variable x_1 is not significant, so his coefficient is 0):

$$x_{10} - 0.2299x_2 - 4.1929 \geq 0 \qquad (C8)$$

$$x_{10} - 0.5607x_2 - 4.4727 \leq 0 \qquad (C9)$$

Finally, the relation between the socioeconomic index (x_1), gender (x_2) and and the number of hours dedicated to reading (x_{11}) is obtained as:

$$x_{11} + 0.1523x_1 - 0.0281x_2 - 3.4280 \geq 0 \qquad (C10)$$

$$x_{11} + 0.0166x_1 - 0.3354x_2 - 3.6615 \leq 0 \qquad (C11)$$

5. The solution approach.

In this Section, we will further describe the solution approach followed to obtain different possible profiles of students taking into account different coefficient settings which are herein given as interval coefficients. These profiles are then computed according to a surrogate objective function that has been established through a reference point approach and that also considers different sets of weight vectors depending on the importance of each objective. The solution approach herein employed was inspired in the one proposed by Henriques et al. (2019), which enables computing "possibly" efficient solutions (i.e. efficient solutions for at least one of the possible combinations of the objective function coefficients) considering an achievement scalarizing function.

5.1. Underpinning assumption and notation

Interval programming has many possible formulations (see e.g. Henriques et al. 2020 and Gabrel et al., 2010). The specific multiobjective programming models with interval coefficients herein tackled can be generically specified as:

$$\max Z_k(\mathbf{x}) = \sum_{j=1}^{n}[c_{kj}^L, c_{kj}^U]\, x_j, \quad k = 1, \dots, p,$$
$$s.t.: \boldsymbol{x} \in X \qquad (1)$$

where $[c_{kj}^L, c_{kj}^U]$ is the interval valued vector of objective function coefficients, $\mathbf{x} = (x_1, \dots, x_n)^T$ is the vector of decision variables and $X = \{\mathbf{x} = (x_1, \dots, x_n)^T \in \mathbb{R}^n \mid \sum_{j=1}^{n} a_{ij}x_j \leq b_i \;\; i = 1, \dots, m, \;\; x_j \geq 0, \;\; j = 1, \dots, n\}$ is the feasible region.

If the coefficients of the objective function are transformed into a real value, $\bar{c}_{kj} \in [c_{kj}^L, c_{kj}^U]$ for all $k = 1, \dots, p, j = 1, \dots, n$, then problem (1) becomes an MOLP problem:

$$\max \bar{Z}_k(\mathbf{x}) = \sum_{j=1}^{n} \bar{c}_{kj}\, x_j, \qquad k = 1, \dots, p,$$
$$s.t.: \boldsymbol{x} \in X \qquad (2)$$

The ideal solutions are computed by using the upper bounds of each objective function being maximized (the lower bounds for the objective functions being minimized) in the best-case scenario and the reverse situation in the worst-case scenario (Chinneck and Ramadan, 2000). For each *k =1, …, p*, the following linear programming problems are solved:

$$\max Z_k^U(\mathbf{x}) = \sum_{j=1}^{n} c_{kj}^U\, x_j,$$
$$s.t.: \boldsymbol{x} \in X \qquad (3)$$

and

$$\max Z_k^L(\mathbf{x}) = \sum_{j=1}^{n} c_{kj}^L\, x_j$$
$$s.t.: \boldsymbol{x} \in X \qquad (4)$$

where $\mathbf{x}_k^U$ and $\mathbf{x}_k^L$ are the optimal solutions to problems (3) and (4), respectively, and, the corresponding objective function values are given as:

$$Z_k^{U^*} = Z_k^U(\mathbf{x}_k^U), \qquad k = 1, \dots, p, \qquad (5)$$
$$Z_k^{L^*} = Z_k^L(\mathbf{x}_k^L), \qquad k = 1, \dots, p. \qquad (6)$$

The intervals $[Z_k^{L^*}, Z_k^{U^*}]$ with $k = 1, \dots, p$ correspond to the interval ideal solutions (Oliveira and Antunes, 2009).

Definition 1 - A solution $\mathbf{x}' \in X$ is an efficient solution to the problem (2) if and only if there is no other solution $\mathbf{x} \in X$, such that $\bar{Z}_k(\mathbf{x}') \leq \bar{Z}_k(\mathbf{x})$ for all objectives with at least one strict inequality.

Definition 2 - A solution $\mathbf{x}' \in X$ is a necessarily efficient solution to problem (1) if and only if it is efficient to problem (2) for any $\bar{c}_{kj} \in [c_{kj}^L, c_{kj}^U]$ for all $k = 1, \dots, p$, $j = 1, \dots, n$.

Definition 3 - A solution $\mathbf{x}' \in X$ is a possibly efficient solution to problem (1) if it is an efficient solution to problem (2) for at least one $\bar{c}_{kj} \in [c_{kj}^L, c_{kj}^U]$ for all $k = 1, \dots, p$, $j = 1, \dots, n$.

The sets of necessarily and possibly efficient solutions are denoted by N_E and P_E, respectively. From the previous definitions, it can be concluded that $N_E \subseteq P_E$, i.e. any solution to an interval MOLP should belong to one of these sets (N_E or P_E). However, since the existence of N_E is not guaranteed and P_E may contain an infinite number of elements, a convenient method to obtain solutions is required.

In this context, to define the scalarizing surrogate problems, we use the idea of the reference point approach for the deterministic problems proposed by Wierzbicki (1980). This approach has excellent properties in terms of the efficiency of the solutions and the possibility of generating the whole optimal Pareto set (for more details, see Miettinen, 1999). The reference point approach has some similarities with goal programming as it is indicated in Ogryczak (1994) and, even, can be used to carry out a visual exploration to characterize the set of efficient solutions (Costa et al., 2005). In addition, there are more works where these similarities are analysed as for example in Romero et al. (1998).

5.2. The scalarizing surrogate problems

The surrogate problems are obtained by considering that the decision-maker (DM) wants to minimize the worst possible distance of each interval objective function to an interval target by considering the concept of necessary deviation (Inuiguchi and Kume, 1991).

The necessary deviation $E(\mathbf{x}) = [e^L(\mathbf{x}), e^U(\mathbf{x})]$ from $Z_k(\mathbf{x}) = \left[\sum_{j=1}^n c_{kj}^L x_j = Z_k^L(\mathbf{x}), \sum_{j=1}^n c_{kj}^U x_j = Z_k^U(\mathbf{x})\right]$ to an interval target $T_k = [t_k^L, t_k^U]$ is:

$$E(\mathbf{x}) = \begin{cases} \left|\left[t_k^L - \sum_{j=1}^n c_{kj}^L x_j, t_k^U - \sum_{j=1}^n c_{kj}^U x_j\right]\right| \; if \; t_k^U - t_k^L \geq \sum_{j=1}^n (c_{kj}^U - c_{kj}^L) x_j, \\ \left|\left[\sum_{j=1}^n c_{kj}^L x_j - t_k^L, \sum_{j=1}^n c_{kj}^U x_j - t_k^U\right]\right| \; if \; \sum_{j=1}^n (c_{kj}^U - c_{kj}^L) x_j \geq t_k^U - t_k^L, \end{cases}$$

$$E(\mathbf{x}) =$$

$$\begin{cases} \left[t_k^L - \sum_{j=1}^n c_{kj}^L x_j, t_k^U - \sum_{j=1}^n c_{kj}^U x_j\right] \; if \; t_k^U - \sum_{j=1}^n c_{kj}^U x_j \geq t_k^L - \sum_{j=1}^n c_{kj}^L x_j \geq 0, \\ \left[0, \left(t_k^U - \sum_{j=1}^n c_{kj}^U x_j\right) \vee \left(\sum_{j=1}^n c_{kj}^L x_j - t_k^L\right)\right] \; if \; t_k^L - \sum_{j=1}^n c_{kj}^L x_j < 0 < t_k^U - \sum_{j=1}^n c_{kj}^U x_j, \\ \left[\sum_{j=1}^n c_{kj}^U x_j - t_k^U, \sum_{j=1}^n c_{kj}^L x_j - t_k^L\right] \; if \; t_k^L - \sum_{j=1}^n c_{kj}^L x_j \leq t_k^U - \sum_{j=1}^n c_{kj}^U x_j \leq 0, \\ \left[\sum_{j=1}^n c_{kj}^L x_j - t_k^L, \sum_{j=1}^n c_{kj}^U x_j - t_k^U\right] \; if \; \sum_{j=1}^n c_{kj}^U x_j - t_k^U \geq \sum_{j=1}^n c_{kj}^L x_j - t_k^L \geq 0, \\ \left[0, \left(\sum_{j=1}^n c_{kj}^U x_j - t_k^U\right) \vee \left(t_k^L - \sum_{j=1}^n c_{kj}^L x_j\right)\right] \; if \; \sum_{j=1}^n c_{kj}^L x_j - t_k^L < 0 < \sum_{j=1}^n c_{kj}^U x_j - t_k^U, \\ \left[t_k^U - \sum_{j=1}^n c_{kj}^U x_j, t_k^L - \sum_{j=1}^n c_{kj}^L x_j\right] \; if \; \sum_{j=1}^n c_{kj}^L x_j - t_k^L \leq \sum_{j=1}^n c_{kj}^U x_j - t_k^U \leq 0. \end{cases}$$

Let the chosen interval targets be given by the interval ideal solutions defined in (5) and (6):

$$T_k = [t_k^L, t_k^U] = \left[Z_k^{L^*}, Z_k^{U^*}\right], \tag{7}$$

where the deviational variables are defined in such a way that

$$e_k^L = Z_k^{L^*} - \sum_{j=1}^{n} c_{kj}^L x_j \geq 0,\ e_k^U = Z_k^{U^*} - \sum_{j=1}^{n} c_{kj}^U x_j \geq 0.$$

Hence, the previous necessary regret interval can be obtained as:

$$E(\mathbf{x}) = [e^L(\mathbf{x}), e^U(\mathbf{x})] = [\lambda \sum_{k=1}^{p} \gamma_k\, (e_k^L \wedge e_k^U) + (1-\lambda) \vee_{k=1}^{p} (e_k^L \wedge e_k^U), \\ \lambda \sum_{k=1}^{p} \gamma_k\, (e_k^L \vee e_k^U) + (1-\lambda) \vee_{k=1}^{p} (e_k^L \vee e_k^U)] \quad (8)$$

where $0 \leq \lambda \leq 1$.

Considering that, for real values, the "$\wedge$" and "$\vee$" operators are the minimum and maximum values respectively, the necessary regret interval can be expressed as:

$$E(\mathbf{x}) = [e^L(\mathbf{x}), e^U(\mathbf{x})] = \\ \left[\lambda \sum_{k=1}^{p} \gamma_k \min\{e_k^L, e_k^U\} + (1-\lambda) \max_{k=1,\dots,p} \left\{\min\{e_k^L, e_k^U\}\right\}, \\ \lambda \sum_{k=1}^{p} \gamma_k \max\{e_k^L, e_k^U\} + (1-\lambda) \max_{k=1,\dots,p} \left\{\max\{e_k^L, e_k^U\}\right\}\right] \quad (9)$$

It is evident that $\max_{k=1,\dots,p} \left\{\max\{e_k^L, e_k^U\}\right\} = \max_{k=1,\dots,p} \{e_k^L, e_k^U\}$.

If the DM wishes to minimize the maximum necessary regret of each interval objective function from its corresponding interval target problem (1), (s)he has the following surrogate problem:

$$\begin{aligned} & \min \max E(\mathbf{x}) \\ & s.t.: \sum_{j=1}^{n} c_{kj}^L x_j + e_k^L = Z_k^{L*}, && k = 1, \dots, p, \\ & \sum_{j=1}^{n} c_{kj}^U x_j + e_k^U = Z_k^{U*}, && k = 1, \dots, p, \\ & \sum_{j=1}^{n} a_{ij} x_j \leq b_i, && i = 1, \dots, m, \\ & x_j \geq 0, && j = 1, \dots, n. \quad (10) \end{aligned}$$

Problem (10) can either be solved by considering an optimistic (the lower bound of the necessary deviation) or a pessimistic procedure (the upper bound of the necessary deviation). The second procedure allows obtaining the smallest distance from the target considered (Oliveira and Antunes, 2007; Inuiguchi and Kume, 1991). Therefore, we consider the following surrogate problem:

$$\begin{aligned} & \min v, \\ & s.t.: \sum_{j=1}^{n} c_{kj}^L x_j + e_k^L = Z_k^{L*}, && k = 1, \dots, p, \\ & \sum_{j=1}^{n} c_{kj}^U x_j + e_k^U = Z_k^{U*}, && k = 1, \dots, p, \\ & \sum_{j=1}^{n} a_{ij} x_j \leq b_i, && i = 1, \dots, m, \\ & e_k^L \leq u_k, && k = 1, \dots, p, \\ & e_k^U \leq v_k, && k = 1, \dots, p, \\ & u_k \leq u^U, && k = 1, \dots, p, \\ & v_k \leq u^U, && k = 1, \dots, p, \\ & \lambda_1 \sum_{k=1}^{p} \gamma_k u_k + \lambda_2 \sum_{k=1}^{p} \alpha_k v_k + \lambda_3 u^u \leq v \\ & \sum_{k=1}^{p} \gamma_k = 1 \\ & \sum_{k=1}^{p} \alpha_k = 1 \\ & \lambda_1 + \lambda_2 + \lambda_3 = 1 && \lambda_1, \lambda_2, \lambda_3 \geq 0 \\ & x_j \geq 0, && j = 1, \dots, n. \\ & \gamma_j \geq 0, && j = 1, \dots, n. \\ & \alpha_j \geq 0, && j = 1, \dots, n. \quad (11) \end{aligned}$$

This problem considers a linear combination of the L_1 metric and L_∞ metric (Tchebychev distance) through the variables e_k^L, e_k^U, u_k, v_k, u^U and v.

As it is pointed out previously, since that e_k^L and e_k^U for all $k = 1, \dots, p$ are always positive values (Z_k^{L*} and Z_k^{U*} are ideal optimal values for $\sum_{i=1}^{n} c_{ki}^L x_i$ and $\sum_{i=1}^{n} c_{ki}^U x_i$, respectively), the first two sets of constraints of problem (11) can be simplified and e_k^L

and e_k^U for all $k = 1, \dots, p$ are not necessary. Thus, we propose a scalarizing problem equivalent to (11) whose formulation is simplified:

$$
\begin{aligned}
&\min\ v \\
&\text{s.t. } \left(Z_k^{L*} - \textstyle\sum_{j=1}^{n} c_{kj}^{L}\, x_j\right) \le u_k, && k = 1, \dots, p \\
&\left(Z_k^{U*} - \textstyle\sum_{j=1}^{n} c_{kj}^{U}\, x_j\right) \le v_k, && k = 1, \dots, p \\
&\textstyle\sum_{j=1}^{n} a_{ij} x_j \le b_i, && i = 1, \dots, m \\
&u_k \le u^u, && k = 1, \dots, p \\
&v_k \le u^u, && k = 1, \dots, p \\
&\lambda_1 \textstyle\sum_{k=1}^{p} \gamma_k u_k + \lambda_2 \sum_{k=1}^{p} \alpha_k v_k + \lambda_3 u^u \le v \\
&\textstyle\sum_{k=1}^{p} \gamma_k = 1 \\
&\textstyle\sum_{k=1}^{p} \alpha_k = 1 \\
&\lambda_1 + \lambda_2 + \lambda_3 = 1 && \lambda_1, \lambda_2, \lambda_3 \ge 0 \\
&x_j \ge 0, && j = 1, \dots, n. \\
&\gamma_j \ge 0, && j = 1, \dots, n. \\
&\alpha_j \ge 0, && j = 1, \dots, n. \qquad (12)
\end{aligned}
$$

Finally, for each "possibly" efficient solution obtained, the following information is presented to the DM, which allows him/her to express his/her preferences.

1) The degree of acceptability of the solution obtained being inferior to the interval ideal solution, i.e., $A \prec (Z_k(x), Z_k^*) = \frac{m[Z_k^*] - m[Z_k(x)]}{w[Z_k^*] - w[Z_k(x)]}$, where $m[Z_k^*]$ and $m[Z_k(x)]$ are the central values of the intervals and $w[Z_k^*]$ and $w[Z_k(x)]$ are the width of the intervals as defined in Sengupta et al. (2001).
2) The distance from $[Z_k(x)]$ to the target $[Z_k^*]$, i.e. $d\ (Z_k^*\ , Z_k\ (x))\ =\ max(\ |Z_k^{L^*} - Z_k^L(x)|, |Z_k^{U^*} - Z_K^U(x)|)$.
   When both the distance and the degree of acceptability are close to zero, the interval objective functions are closer to their corresponding interval ideal solutions.
3) The degree of achievement of the solution obtained with respect to the corresponding the lower and upper targets i.e. $t_{ck}^L = 1 - \frac{Z_k^{L^*} - Z_k^L(x)}{Z_k^{L^*} - m_k^L}$ and $t_{ck}^U = 1 - \frac{Z_k^{U^*} - Z_k^U(x)}{Z_k^{U^*} - m_k^U}$ where m_k^L and m_k^U are the worst values attained in the expanded pay-off table. The closer the values of t_{ck}^L and t_{ck}^U are to 1, the closer DM is to meet his/her aspiration level Z_k^*.

6. Discussion of results

The first step of our analysis consists of obtaining the individual optimal values of each objective function under a worst- and a best-case scenario, i.e. the ideal interval values corresponding to each objective function. In this way, it is possible to obtain a global overview of the students' profiles consistent with the optimization of each index both considering pessimistic and optimistic scenarios. Let us remember that, in our model, Z_1 and Z_4 are to minimize and Z_2 and Z_3 to maximize:

$Z_1^{U^*} = Z_1^U(x_1^U) = -0.7325$; $\quad Z_2^{U^*} = Z_2^U(x_2^U) = 0.8976$;
$Z_3^{U^*} = Z_3^U(x_3^U) = 0.5755$; $\quad Z_4^{U^*} = Z_4^U(x_4^U) = -0.3381$;
$Z_1^{L^*} = Z_1^L(x_1^L) = -0.1450$; $\quad Z_2^{L^*} = Z_2^L(x_2^L) = 0.3647$;
$Z_3^{L^*} = Z_3^L(x_3^L) = -0.0705$; $\quad Z_4^{L^*} = Z_4^L(x_4^L) = 0.0395$.

The socioeconomic index (escs) reaches the maximum value of the sample in each individual optimum irrespective of the scenario considered. Boys always attain both the minimum levels of anxiety and the maximum levels of motivation (other studies also corroborate similar findings – see e.g. Dilshad et al., 2019; Akib et al., 2018). Girls achieve the minimum bullying value. Semi-private schools are always associated with the maximum sense of belonging regardless of the scenario considered. In the case of the maximum level of motivation a difference arises between the scenarios considered, i.e. in the worst-case scenario public schools are related with the maximum level of motivation, whereas semi-private schools are associated with the maximum level of motivation in the opposite scenario. The number of hours of internet use outside school obtains similar values in each objective; however, the highest value attained for this variable is reached when the maximization of the sense of belonging takes place. In order to minimize the anxiety levels and to maximize the motivation levels the ideal age to start using digital devices and internet is around 6 and 7 years old, respectively. The ideal number of hours devoted to studying math in order to minimize the anxiety levels and to maximize both the motivation and the sense of belonging levels should be between 4 and 5 hours per week. Finally, 3 hours of reading per week allow minimizing the levels of anxiety and the levels of bullying suffered.

Table 2. Students' ideal profiles.

	Lower bound				Upper bound			
	Anxiety	Motivation	Sense of belonging	Bullying	Anxiety	Motivation	Sense of belonging	Bullying
Escs	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271
Semi-private	0	0	1	0	0	1	1	0
Second period	0	0	0	0	0	0	0	0
Third period	0	0	1	0	0	0	1	0
Fourth period	0	0	0	0	1	0	0	0
Girls	0	0	0	1	0	0	0	1
Internet outside school	2.2742	2.2742	3.2604	2.2742	2.8012	2.5229	3.2604	2.2742
Age at use digital devices	5.6846	5.6846	6.1824	5.6846	5.6846	6.1824	6.1824	5.6846
Age at use internet	6.9434	6.9434	7.2476	6.9434	7.3860	7.2476	7.2476	6.9434
Hours of math	4.1929	4.4727	5.0335	4.1929	4.1929	5.0335	5.0335	4.1929
Hours of reading	2.9297	2.9297	2.9578	2.9297	2.9297	2.9578	2.9578	2.9297

In order to explore different balanced solutions in terms of student's well-being, different possible weights were assigned to reach each objective function. In this context, the distinct combinations of weights used in our analysis are depicted in Table 3. The first set of weights $(\lambda_1, \lambda_2, \lambda_3)$ refers to the scenarios considered, i.e. giving a higher weight to the worst-case scenario (pessimistic scenario), to the best-case scenario (optimistic scenario) or both scenarios at the same time. The second one $(\gamma_1, \gamma_2, \gamma_3, \gamma_4)$ represents the importance of each objective (anxiety, motivation, sense of belonging, and bullying) in the worst-case scenario and, the last one $(\alpha_1, \alpha_2, \alpha_3, \alpha_4)$ shows the importance of each objective in the best-case scenario. Overall, we computed sixteen solutions, the first eight following a pessimistic scenario and the remaining more consistent with an optimistic scenario. Specifically, when $\lambda_1 = 0.8$, the DM is assigning a higher importance to obtaining the ideal solution in the worst-case scenario (assuming a more conservative stance), whereas when $\lambda_2 = 0.8$ the DM is assigning a higher importance to obtaining the ideal solution in the best-case scenario (assuming a more optimistic stance).

Table 3. Parameters considered in each solution.

Parameters considered in each solution											
	λ_1	λ_2	λ_3	γ_1	γ_2	γ_3	γ_4	α_1	α_2	α_3	α_4
Sol 1	0.8	0.1	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sol 2	0.8	0.1	0.1	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.7
Sol 3	0.8	0.1	0.1	0.1	0.05	0.05	0.8	0.1	0.05	0.05	0.8
Sol 4	0.8	0.1	0.1	0.4	0.1	0.1	0.4	0.4	0.1	0.1	0.4
Sol 5	0.8	0.1	0.1	0.7	0.1	0.1	0.1	0.7	0.1	0.1	0.1
Sol 6	0.8	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.7	0.1	0.1
Sol 7	0.8	0.1	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.7	0.1
Sol 8	0.8	0.1	0.1	0.1	0.4	0.4	0.1	0.1	0.4	0.4	0.1
Sol 9	0.1	0.8	0.1	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sol 10	0.1	0.8	0.1	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.7
Sol 11	0.1	0.8	0.1	0.1	0.05	0.05	0.8	0.1	0.05	0.05	0.8
Sol 12	0.1	0.8	0.1	0.4	0.1	0.1	0.4	0.4	0.1	0.1	0.4
Sol 13	0.1	0.8	0.1	0.7	0.1	0.1	0.1	0.7	0.1	0.1	0.1
Sol 14	0.1	0.8	0.1	0.1	0.7	0.1	0.1	0.1	0.7	0.1	0.1
Sol 15	0.1	0.8	0.1	0.1	0.1	0.7	0.1	0.1	0.1	0.7	0.1
Sol 16	0.1	0.8	0.1	0.1	0.4	0.4	0.1	0.1	0.4	0.4	0.1

Tables 4 and 5 provide the objective function values and the students' profiles attained in each solution. In addition, the acceptability degree of the solution, the distance from the ideal solution and the lower and upper achievement rates of the objective function values regarding the corresponding lower and upper targets are given in Table 6.

In the worst-case scenario ($\lambda_1 = 0.8, \lambda_2 = 0.1, \lambda_3 = 0.1$) we have started the search for solutions by assigning the same weights to the objective functions, meaning that $\gamma_k = 0.25$ and $\alpha_k = 0.25$, when $k = 1, 2, 3, 4$, leading to compute Sol 1. The acceptability degree of this solution being inferior to its ideal optimal value and the distance from the ideal value to it are higher both for the case of the minimization of bullying (0.1737) and the maximization of the sense of belonging (0.1531). Nonetheless, the levels of anxiety and motivation reach values near the ideal, which are also corroborated by the lower and upper achievement rates of these objective functions ($tc_1^l = 1$ and $tc_1^u = 0.9782$ for the minimization of anxiety, and $tc_1^l = 0.9905$ and $tc_1^u = 0.8513$ for the maximization of motivation). Finally, it is possible to observe the conflicting trade-off between the minimization of bullying and anxiety levels, because the relation between the lower and upper achievement rates of this latter indicator are both very high (reaching 100% $-$ $tc_1^l = 1$ $-$ and 97.82% $-tc_1^u = 0.9782$ $-$, respectively), whereas in the case of bullying are both low, especially in the upper achievement rate (achieving a lower achievement rate of 61.30% and an upper achievement of 17.98%).

Table 4. Objective function values of each solution.

	Lower case ($Z^L(x_k)$)				Upper case ($Z^U(x_k)$)			
	Anxiety	Motivation	Sense of belonging	Bullying	Anxiety	Motivation	Sense of belonging	Bullying
Sol 1	-0.145	0.3637	-0.0912	0.1397	-0.7259	0.8887	0.4224	-0.1644
Sol 2	0.215	0.2506	-0.0912	0.0395	-0.4313	0.8378	0.4224	-0.3381
Sol 3	0.215	0.2506	-0.0912	0.0395	-0.4313	0.8378	0.4224	-0.3381
Sol 4	-0.145	0.3637	-0.0912	0.1397	-0.7259	0.8887	0.4224	-0.1644
Sol 5	-0.145	0.3637	-0.0912	0.1397	-0.7259	0.8887	0.4224	-0.1644

	Lower case ($Z^L(x_k)$)				Upper case ($Z^U(x_k)$)			
	Anxiety	Motivation	Sense of belonging	Bullying	Anxiety	Motivation	Sense of belonging	Bullying
Sol 6	-0.137	0.3647	-0.0907	0.1397	-0.7221	0.8933	0.4272	-0.1644
Sol 7	-0.137	0.3647	-0.0907	0.1397	-0.7221	0.8933	0.4272	-0.1644
Sol 8	-0.137	0.3647	-0.0907	0.1397	-0.7221	0.8933	0.4272	-0.1644
Sol 9	-0.1	0.3473	-0.072	0.2819	-0.71	0.8976	0.5609	-0.13
Sol 10	0.215	0.2506	-0.091	0.0395	-0.431	0.8378	0.4224	-0.338
Sol 11	0.215	0.2506	-0.091	0.0395	-0.431	0.8378	0.4224	-0.338
Sol 12	-0.145	0.3637	-0.091	0.1397	-0.726	0.8887	0.4224	-0.164
Sol 13	-0.145	0.3637	-0.091	0.1397	-0.726	0.8887	0.4224	-0.164
Sol 14	-0.137	0.3647	-0.091	0.1397	-0.722	0.8933	0.4272	-0.164
Sol 15	-0.09	0.3334	-0.071	0.2982	-0.711	0.8934	0.5755	-0.126
Sol 16	-0.09	0.3334	-0.071	0.2982	-0.711	0.8934	0.5755	-0.126

Since the most affected feature of well-being in the previous solution (Sol 1) is the minimization of the bullying index, we will assign in the next two solutions a higher weight to this objective function, keeping the assumption of having a pessimistic stance. In this case we have opted to solve two problems: one considering that the bullying index has a weight of 70% and the remaining objectives are assigned with weights of 10% each (Sol 2); another problem where the bullying index has a weight of 80%, the anxiety index has a weight of 10% and the motivation and sense of belonging indexes are assigned with weights of 5% each (Sol 3). It is interesting to see that the solutions thus obtained are similar. The bullying index in these solutions achieves its ideal value (with lower and upper achievement rates of 100%), but anxiety and the motivation indexes get worse (anxiety increases from -0.1450 to 0.2150, whereas motivation decreases from 0.3637 to 0.2506). Another difference between these two solutions and the previous one refers to the optimal student's profile (see Table 5) in terms of gender, i.e. the minimum levels of bullying corresponding to the ideal solution are related to girls. According to the econometric analysis performed in Section 3.2, girls tends to have more anxiety and less motivation than boys. Therefore, if the student's profile associated to the ideal levels of bullying is associated with girls, both anxiety and motivation indexes get worse.

If the same importance is given to the minimization of the anxiety and bullying levels (both with weights of 40%) while the maximization of motivation and sense of belonging have weights of 10% each (Sol 4), the results obtained are similar to those of Sol 1. The same findings are also obtained when considering a weight of 70% assigned to the anxiety index and weights of 10% allocated to the remaining objective functions (Sol 5). Consequently, it is easier to minimize the anxiety levels than minimizing the bullying levels when both objective functions have the same importance.

Finally, we have explored other solutions considering a higher importance given to the maximization of the sense of belonging and motivation when compared to the other two objective functions (Sol 6, 7 and 8). Concretely, Sol 6 gives an importance of 70% to the maximization of the levels of motivation, whereas a 10% weight is given to all the other objective functions. Sol 7 assigns a weight of 70% to the maximization of the sense of belonging, leaving a 10% weight to the remaining aspects of well-being. Finally, Sol 8 gives the same importance to the maximization of the levels of motivation and to the sense of belonging, and an importance of 10% is left to the minimization of the levels of anxiety and bullying. These three last solutions are very similar to the first one (which gives the same importance to each objective function), so we obtain values very close to the ideal anxiety and motivation indexes, while the sense of belonging increases a little bit, but the levels of bullying remain the same. These results are due to the increase of hours dedicated to studying math per week in the student's profile (when compared to Sol 1).

Overall, we can conclude that under a pessimistic scenario we can observe that there is some variability among the different solutions when the importance of each objective is not the same. However, it is important to mention that the sense of belonging obtains a similar value across all solutions analyzed so far. Therefore, this axe of evaluation of well-being remains immune to the changes of weights.

If we consider an optimistic scenario $(\lambda_1 = 0.1, \lambda_2 = 0.8, \lambda_3 = 0.1)$, we can observe that the sense of belonging attains higher levels of variability when contrasted to the pessimistic scenario. When we give the same importance to all the objective functions (Sol 9), the first three objective functions reach values near their ideal solutions because their lower and upper achievement rates are close to 1 (reaching, for example, for the maximization of the sense of belonging 97.49% $- tc_9^l = 0.9749$ $-$ and 95.25% $- tc_1^u = 0.9525$). Nevertheless, both achievement rates of the levels of bullying reach values very close to 0. Therefore, we might ascertain that when giving the same importance to all features of well-being, the most harmed aspect of evaluation is the levels of bullying (even worse results are obtained than those reached in a pessimistic scenario, in Sol 1). Unlike Sol 1, the student's profile suggests that these students are enrolled in a semi-private school. Hence, the sense of belonging obtains a value closer to the ideal solution. Additionally, the starting age for using digital devices (6.2 against 5.7) and internet (7.2 against 6.9) is higher and they spend one more hour studying mathematics per week (5 against 4 hours).

Like we have done in the pessimistic scenario, we now give more importance to the minimization of bullying when contrasted with the remaining objective functions (Sol 10 and Sol 11). Analogously to what happened in the worst-case scenario (Sol 2 and 3), the bullying index reaches its ideal levels. However, the anxiety and motivation indexes get significantly worse, thus reaching the worst possible values of the whole sample of solutions analyzed (i.e. [-0.4313, 0.215] in the anxiety index and [0.2506, 0.8373] in the motivation index). Furthermore, the sense of belonging worsens with respect to Sol 9.

When we give the same importance to the minimization of bullying and anxiety levels (Sol 12) we are able to highlight once more the conflicting trade-off between these two objective functions. Nevertheless, this solution is more balanced than Sol 10 and Sol 11. Now the anxiety levels achieve values close to the corresponding lower and upper ideal values, although the bullying index gets worse than in the previous two solutions, particularly in the upper achievement rate where $tc_{12}^u = 0.1798$. Regarding the motivation index, it almost achieves its interval ideal value. On the other hand, the sense of belonging does not change with respect to the previous values attained (Sol 10 and 11). This is due to the change of gender in the student's profile that is now composed of boys. It is also interesting to note that if we give more importance to the minimization of the anxiety index (Sol 13) we obtain the same results of Sol 12. If we give a higher priority to the motivation index (Sol 14), this objective achieves values very near to its interval ideal solution, but at the expense of worsening the levels of bullying. These results occur because boys are usually more motivated but more bullied than girls. Lastly, giving more importance to the maximization of the sense of belonging (Sol 15) and the same importance to the maximization of motivation and the sense of belonging (Sol 16) leads to identical solutions. In this case, the sense of belonging achieves the corresponding interval ideal value and the anxiety and motivation indexes reach values close to their ideals. However, the bullying index obtains the worst values possible from the sample of solutions under scrutiny. Therefore, maximizing the sense of belonging leads to significantly worsen results for bullying. This is because the type of school attained in the student's profile is different in the ideal optimum of both indexes. Students enrolled in a semi-private school have more sense of belonging but are also more bullied.

It should be noted that these results highlight the need of paying special attention to bullying, since this is the most affected feature of student's well-being in both scenarios.

7. Conclusions

This paper proposes a novel approach to appraise the trade-offs across different features of students' well-being. A multiobjective interval programming model was formulated, which was instantiated through the confidence intervals obtained in several OLS estimations. The second stage of our analysis consisted of obtaining different students' profiles depending on the importance assigned to each component of students' well-being (i.e. anxiety, motivation, sense of belonging and bullying).

One of the main advantages of this analysis is that it enables understanding how the improvement of one objective affects the other objectives, allowing to anticipate the impacts of education policies on the measures of well-being herein contemplated.

Overall, our findings suggest that boys are more bullied than girls. Additionally, it was also possible to conclude that it is hard to minimize the levels of bullying without compromising the remaining components of students' well-being. Therefore, some preventive measures should be promoted in order to avoid this phenomenon. Further work should be developed in terms of educational content that specifically addresses social and emotional skills to respond to bullying behaviours. Other possibilities could include making a list of classroom rules and analyse real cases of bullying with the aim of encouraging trust with teachers. The reporting of bullying could improve the effectiveness of anti-bullying interventions. Finally, with this regard, since the experience of numerous anti-bullying programs is not new, other references of best-practices could be followed, such as the Olweus Bullying Prevention Program (OBBPP) in Norway (Olweus and Limber ,1983), the Seville Anti-Bullying in School Project (SAVE Project) (Ortega and Lera, 2000), the Sheffield Anti-Bullying Project in England (Sharp and Smith, 1991) and the KiVa Anti-Bullying Program in Finland (Salmivalli et al.,2010). According to these programs, material for students, teachers and parents should be provided with the aim of reducing bullying in the classrooms. For instance, the KiVa program tries to improve the empathy towards the bullied peers and offers a plan to support them, through discussion in lessons, videos and online computer games.

In order to minimize the anxiety levels and to maximize the motivation levels, our findings suggest that the ideal age to start using digital devices and internet is around 6 and 7 years old, respectively. Furthermore, the ideal number of hours dedicated to studying math in order to minimize the anxiety levels and to maximize both the motivation and the sense of belonging levels should be between 4 and 5 hours per week. Additionally, 3 hours of reading per week seem to help minimize the levels of anxiety and the levels of bullying suffered.

Finally, since girls tend to be more affected by anxiety than boys, further work should be developed with girls regarding the feelings of failure and the importance of other people's opinions within grouping therapies and practices (see e.g. Mann and Walshaw, 2019).

Regarding the sense of belonging (the more balanced feature of students' well-being across all solutions under scrutiny), since the family and school are important to improve the sense of belonging (see e.g. Allen et al.,2018), the organization of several initiatives could be promoted in which family members and students establish a closer contact and are able to get to know each other.

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Table 5. Optimal solutions to the interval multiobjective model.

Decision variables	Sol 1	Sol 2	Sol 3	Sol 4	Sol 5	Sol 6	Sol 7	Sol 8	Sol 9	Sol 10	Sol 11	Sol 12	Sol 13	Sol 14	Sol 15	Sol 16
Escs	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271	3.271
Semi-private schools	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	1
Second period	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Third period	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fourth period	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Girls	0	1	1	0	0	0	0	0	0	1	1	0	0	0	0	0
Internet outside school	2.2742	2.2742	2.2742	2.2742	2.2742	2.2742	2.2742	2.2742	2.5229	2.2742	2.2742	2.2742	2.2742	2.2742	3.2604	3.2604
Age at use digital devices	5.6846	5.6846	5.6846	5.6846	5.6846	5.6846	5.6846	5.6846	6.1824	5.6846	5.6846	5.6846	5.6846	5.6846	6.1824	6.1824
Age at use Internet	6.9434	6.9434	6.9434	6.9434	6.9434	6.9434	6.9434	6.9434	7.2476	6.9434	6.9434	6.9434	6.9434	6.9434	7.2476	7.2476
Hours of math	4.1929	4.1929	4.1929	4.1929	4.1929	4.4727	4.4727	4.4727	5.0335	4.1929	4.1929	4.1929	4.1929	4.4727	5.0335	5.0335
Hours of reading	2.9297	2.9297	2.9297	2.9297	2.9297	2.9297	2.9297	2.9297	2.9578	2.9297	2.9297	2.9297	2.9297	2.9297	2.9578	2.9578

Table 6. Information regarding the solutions.

	$A \prec (Z_k(x), Z_k^*)$				$d(Z_k^*, Z_k(x))$				tc_k^l				tc_k^u			
	F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4	F1	F2	F3	F4
Sol 1	0.0056	0.0094	0.1498	0.4018	0.0066	0.0089	0.1531	0.1737	1	0.9905	0.7247	0.6130	0.9782	0.8513	0.5031	0.1798
Sol 2	0.5359	0.1554	0.1498	0	0.3600	0.1142	0.1531	0	0	0	0.7247	1	0	0	0.5031	1
Sol 3	0.5359	0.1554	0.1498	0	0.3600	0.1142	0.1531	0	0	0	0.7247	1	0	0	0.5031	1
Sol 4	0.0056	0.0094	0.1498	0.4018	0.0066	0.0089	0.1531	0.1737	1	0.9905	0.7247	0.6130	0.9782	0.8513	0.5031	0.1798
Sol 5	0.0056	0.0094	0.1498	0.4018	0.0066	0.0089	0.1531	0.1737	1	0.9905	0.7247	0.6130	0.9782	0.8513	0.5031	0.1798
Sol 6	0.0157	0.0041	0.1448	0.4018	0.0104	0.0043	0.1483	0.1737	0.9775	1	0.7306	0.6130	0.9656	0.9278	0.5187	0.1798
Sol 7	0.0157	0.0041	0.1448	0.4018	0.0104	0.0043	0.1483	0.1737	0.9775	1	0.7306	0.6130	0.9656	0.9278	0.5187	0.1798
Sol 8	0.0157	0.0041	0.1448	0.4018	0.0104	0.0043	0.1483	0.1737	0.9775	1	0.7306	0.6130	0.9656	0.9278	0.5187	0.1798
Sol 9	0.0561	0.0161	0.0129	0.5704	0.0448	0.0175	0.0146	0.2424	0.8755	0.8471	0.9749	0.0631	0.9258	1	0.9525	0.0179
Sol 10	0.5359	0.1554	0.1498	0	0.3600	0.1142	0.1531	0	0	0	0.7247	1	0	0	0.5031	1
Sol 11	0.5359	0.1554	0.1498	0	0.3600	0.1142	0.1531	0	0	0	0.7247	1	0	0	0.5031	1
Sol 12	0.0056	0.0094	0.1498	0.4018	0.0066	0.0089	0.1531	0.1737	1	0.9905	0.7247	0.6130	0.9782	0.8513	0.5031	0.1798
Sol 13	0.0056	0.0094	0.1498	0.4018	0.0066	0.0089	0.1531	0.1737	1	0.9905	0.7247	0.6130	0.9782	0.8513	0.5031	0.1798
Sol 14	0.0157	0.0041	0.1448	0.4018	0.0104	0.0043	0.1483	0.1737	0.9775	1	0.7306	0.6130	0.9656	0.9278	0.5187	0.1798
Sol 15	0.0631	0.0325	0	0.5866	0.0547	0.0313	0.0000	0.2587	0.8480	0.7257	1	0	0.9285	0.9298	1	0
Sol 16	0.0631	0.0325	0	0.5866	0.0547	0.0313	0.0000	0.2587	0.8480	0.7257	1	0	0.9285	0.9298	1	0

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Appendix

Table A1. Description of the explanatory variables.

Name	Notation	Variable	Type	Description	Value
escs	x_1	Socioeconomic index	Continuous	Socioeconomic index	[-4.284, 3.2714]
semiprivate	x_2	Semi-private schools	Binary	Type of school (Semi-private 1 - public 0)	0 or 1
		Period of birth:		Trimester of birth (reference group: the first one)	
p2	x_3	Second period	Binary	Second period (April, May and June)	0 or 1
p3	x_4	Third period	Binary	Third period (July, August and September)	0 or 1
p4	x_5	Fourth period	Binary	Fourth period (October, November and December	0 or 1
girls	x_6	Girls	Binary	Girls	0 or 1
hoursinternet	x_7	Hours of internet outside school	Continuous	Hours of internet outside school	[0,7]
agedigital	x_8	Starting age for using digital devices	Continuous	How old were you when you first used a digital device?	[4.5,14.5]
ageinternet	x_9	Starting age for using internet	Continuous	How old were you when you first accessed the Internet?	[4.5,14.5]
hours_math	x_{10}	Number of hours dedicated to the study of Math	Continuous	This school year, approximately how many hours per week do you spend learning in addition to your required school schedule in math?	[0,30]
hours_reading	x_{11}	Number of hours dedicated to reading	Continuous	This school year, approximately how many hours per week do you spend learning in addition to your required school schedule in reading?	[0,30]

Source: Authors' own calculations.

Table A2. Descriptive statistics of variables.

Variables	Notation	Type	Mean	Sd
Anxiety index	y_1	Continuous	0.0363	0.8023
Motivation index	y_2	Continuous	0.1504	0.8278
Belong index	y_3	Continuous	0.0048	0.8719
Bullying index	y_4	Continuous	-0.0322	0.8154
Socioeconomic index	x_1	Continuous	-0.2888	1.1208
Semi-private schools	x_2	Binary	0.3053	0.4605
Period of birth:				
Second period	x_3	Binary	0.2484	0.4321
Third period	x_4	Binary	0.2611	0.4392
Fourth period	x_5	Binary	0.243	0.4289
Girls	x_6	Binary	0.5326	0.4989
Hours of internet outside school	x_7	Continuous	3.3898	2.1562
Age at use digital devices	x_8	Continuous	7.3487	2.613
Age at use internet	x_9	Continuous	8.624	2.4543
Hours of math	x_{10}	Continuous	4.542	3.6649
Hours of reading	x_{11}	Continuous	3.6659	3.3278

Source: Authors' own calculations.