DEMOGRAPHIC IMPLICATIONS ON EDUCATION: A CASE STUDY IN THE PROVINCE OF MANTOVA[1]

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Abstract. The decreasing birth rates in Italy are rapidly transforming the demographic landscape, with forecasts indicating a significant reduction in the youth population over the next ten years.

In this work, using data provided by the National Institute of Statistics and the Ministry of Education and Merit, a statistical model has been developed to estimate the future composition of the student population in the province of Mantova. Specifically, demographic forecasts, school participation rates, and other relevant parameters were analyzed to create a robust predictive framework and answer the following types of questions: "How will the student population change in the province of Mantova, even at the level of school districts, over the next ten years? How many more or fewer classes will there be? What effects will this have on staffing?".

While focusing on the province of Mantova as a case study, the project aims to develop a solid methodology that can be used in all Italian provinces, leveraging the informative resources of official statistics and public administrations, at this historical moment when we are faced with digital innovation and the development of artificial intelligence.

The results of the conducted analysis, besides providing a valuable contribution to local policy-level educational planning, can, once extended nationally, bring objective data into the debate on government educational policy choices, thus helping to prepare the Italian educational system for evolving demographic challenges.

1. Introduction

Medium- and long-term educational planning is a complex and critical challenge to ensure equitable and quality education for all students. Effective educational planning decisions must be supported by accurate data and reliable student

[1] The work is the joint responsibility of the authors. Paragraphs 1 and 2 are attributed to Alberto Vitalini, paragraphs 3, 3.1, 3.2 and 3.3 to Simona Ballabio, paragraph 4 to Rossella Luca, paragraph 5 to Lorenzo Maraviglia.

population forecasts that take into account changing demographic trends and the specific needs of each territory.

In a context in which birth rates are decreasing and population distribution is constantly changing, it is becoming increasingly critical to forecast the number of students and the resources required to meet society's educational needs with greater precision and territorial granularity. In Italy, the National Institute of Statistics (Istat) forecasts a decrease of more than 1 million potential students (3-18 years) over the next 10 years (Istat, 2024). This scenario requires careful planning and efficient management of resources in the education sector.

2. Aims

This paper aims to address this challenge by focusing on the implementation of a policy tool based on a standardised, robust, accessible and simple methodology to estimate the future composition of the student population, as well as class and staffing levels, in different types of schools and at sub-regional level. In particular, a tool that, using data from official statistics, can be easily applied across the country with a level of disaggregation of estimates at provincial and sub-provincial levels.

The work is the result of a collaboration between institutions, including researchers from Istat Lombardy, the Union of Italian Provinces and INVALSI. It aims to explore the challenges and opportunities that the emerging demographic scenario presents for local and national political strategies in the field of education and more broadly for the design of sustainable development strategies. It is part of the broader analysis of statistical measures by Goal of the European Union's 2030 Agenda, specifically referring to Goal 4: "Quality education for all. Provide quality, equitable and inclusive education and promote lifelong learning opportunities for all".

The proposed forecasting tool is characterized by several distinctive features. First, it relies on reliable and consolidated data, drawing from sources such as Istat and the Ministry of Education and Merit (Miur) to ensure robustness and reliability. Second, the statistical model is designed to be intuitive and easily applicable, allowing the offices of the National Statistical System (Sistan) to implement it independently with minimal resource investment. Additionally, the model offers national coverage and territorial granularity, enabling forecasts to be extended across the entire Italian territory. This includes detailed predictions of the student population at a sub-provincial level, down to the scale of school autonomy and individual municipalities, thereby providing a comprehensive view of educational needs and regional disparities. This detailed granularity supports targeted, data-driven planning that transcends administrative boundaries. Finally, the model addresses the limitations of previous approaches, which were often partial or localized, by offering a unified and consistent statistical framework that is applicable nationwide (Filippi & Migliore, 2020; Molina, 2018).

In addition to explaining in detail the methodological aspects underlying the proposed policy tool, this article presents some initial results of its application in the province of Mantova. This example illustrates the tool's potential in supporting local policies in the medium and long term in the field of education (of school sizing) and in the field of school buildings (of building sizing and interventions for the innovation, adaptation and safety of institutions).

3. Data and methods

Starting with the data from individual municipalities, the tool enables predictive estimates by school grade (up to secondary schools) for the student population, for the number of classes/sections and finally for the number of places/chairs needed to ensure basic teaching.

Initial estimates are made at the municipal level, but further aggregations can be performed by grouping neighbouring municipalities, school districts, and provinces. The choice of aggregation level depends on the estimates' uncertainty and, secondarily, on what is considered most suitable to support potential local social policy decisions.

The data underlying the model are the experimental regional and municipal demographic forecasting statistics produced by Istat[2], complemented by demographic statistics always from Istat[3] and data from Miur surveys on enrolment numbers, enrolment types, and class numbers for Infancy, Primary, and Secondary I and II grade schools[4].

In the application of the tool, data from Istat's projections of the resident population as of January 1 2022 were used, assuming a median scenario. It is important to be aware of the limitations and uncertainties of Istat's demographic forecasts: while they ensure overall consistency, they are based on specific assumptions about demographic behaviours regarding birth rates, mortality rates, and migration, which may differ from actual data[5]. Additionally, the specific application includes assumptions about school participation and organization. The forecasts thus represent a "what-if" exercise based on realistic assumptions that may

[2] https://www.istat.it/statistica-sperimentale/previsioni-demografiche-comunali-1-gennaio-2021-2031/
[3] https://demo.istat.it/app/?i=POS&l=it
[4] https://dati.istruzione.it/espscu/index.html?area=anagStu
[5] For details on the methodologies used for the estimates, please refer to the methodological note produced in support of the released data (Istat, 2023).

not be empirically confirmed due to unforeseen changes in individual or organizational behaviours. For instance, the estimate of class numbers is based on the current average number of students per class, but this number could change to improve educational quality offer. Forecasts become more uncertain the further they are from the baseline, especially in smaller geographic areas. Therefore, we limit our predictive estimates to 10 years after the base year, up to 2032. The further we move from the base year, the more the values should be considered as approximations rather than precise estimates.

3.1 Estimated student population

The proposed tool consists of three consequential steps. The first step is the estimation of the student population, based on projections of the resident population in different age groups (corresponding to schools of different grades) and the participation rate.

The formula for this calculation is:

$$N° \ of \ students = Demographic \ forecasts \ per \ age \ group \ (municipalities) * \ Participation \ rate$$

Therefore, data from the resident population projections for individual municipalities and specific age groups are used first. The estimates at supra-municipal level, on the other hand, are the result of aggregations.

Four age groups were considered:

- 3-5 years, representing potential Infancy school students;
- 6-10 years, representing potential Primary school students;
- 11-13 years, representing potential Secondary I grade school students;
- 14-18 years, representing potential Secondary II grade school students.

Since some residents might attend schools outside their local area of residence and because Infancy and Secondary school (for students aged 17 and over) are not compulsory, the estimated student population was calculated by multiplying the population forecasts for the different age groups considered with their relative participation rates. These rates, calculated at territorial level[6], represent, for each school grade, the arithmetic mean of the last 4 years of the ratio between the number of enrolled students and the population of the age groups corresponding to the school grade on 1 January. For our application, with 2022 as the base year, the school years considered are 2018/19, 2019/20, 2020/21 and 2021/22, with the population at 1 January 2019, 2020, 2021 and 2022.

Assuming stable schooling rates over time, changes in the number of enrolled students at different education levels primarily depend on demographic dynamics incorporated in Istat's resident population projections (Istat, 2023). Future projections of the student population are mainly influenced by migration flows and, to a lesser extent, birth and death rates. Given the age brackets considered, errors in the estimates due to variations in mortality rates are negligible, while variations in birth rates, though more uncertain, are limited, affecting only Infancy and Primary school children.

3.2 Estimating classes/sections

The second step in constructing the model involves estimating the number of classes or sections, depending on the school grade.

The formula for this calculation is:

$$Classes/sections = \frac{n° \; of \; students \; per \; grade \; of \; education}{\boldsymbol{\mu} \, (n° \text{ of students per class per grade of education of a.s. } 2018/19, \; 2019/20, \; 2020/21, \; 2021/22)}$$

To estimate the number of classes, the student population estimated in the previous step is divided by the average number of students in a class, per school grade present at provincial level[7], calculated as the arithmetic mean of the last 4 years. The average number of students per class is determined, using data available on the Miur website, as the ratio of enrolments to the number of classes. This calculation helps determine how many classes/sections are needed based on the expected number of students and the average class capacity in the province, assuming that the average number of students per class remains constant over time.

[6] For regional estimates the regional participation rate was calculated, for provincial and sub-provincial estimates the provincial participation rate.

[7] For regional estimates, the regional value was used.

3.3 Estimating posts/chairs

Variations in the number of classes translate into variations in the number of places/chairs needed. The number of places (at Infancy and Primary schools) or chairs (at Secondary schools) in the workforce depends on several factors, primarily the number of classes formed.

This estimate provides an idea of the minimum number of teachers needed to guarantee basic classroom coverage. Additional staff, such as specialists, educators, and support teachers, are not estimated due to policy dependencies and the unavailability of forecast data for children and young people with disabilities, and therefore with special educational needs.

The number of required teachers would increase if the number of classroom hours for students increased, a factor dependent on policy considerations and a balance between educational supply and individual preferences. For example, in Lombardy, there is considerable variability in the average number of hours Primary school students spend in the classroom. It is worth considering whether this reflects individual preferences or constraints defined by the educational offer.

To calculate the number of teachers needed to guarantee basic education, with the caveats just considered, the formula is used:

$$Places/chairs = classes/sections * \frac{\boldsymbol{\mu}\ (school\ timetable\ by\ grade\ of\ education\ of\ \text{a.s. } 2018/19, 2019/20, 2020/21, 2021/22)^{\circ}}{Contractual\ hours}$$

Once the number of classes is obtained, it is multiplied by the ratio of the actual school hours to the contractual hours of a full-time teacher in the public sector (cfr. National Collective Labour Agreement of personnel in the Education and Research sector Period 2019-2021).

The actual school timetable, which reflects the planned hours of lessons for students, is determined from various sources. For Infancy and Primary schools, it is calculated as an arithmetic average of the weighted average of the actual enrolments in the various timetable schemes currently offered by the school system over the last four years. For lower and upper Secondary schools, an average of 30 hours of lessons per week is adopted.

Teachers' contractual hours, representing the number of teaching hours in their employment contracts, are:

- 25 hours for Infancy schools;
- 22 hours for primary schools;
- 18 hours for I and II grade Secondary schools.

4. Results

To highlight the model's potential, we present an application in Lombardy, in the province of Mantova and in two school districts within the province. The tool provides an overall view of future trends, allowing for the identification of the unique characteristics of different territories.

More operationally, it determines the student population, the number of classes, and the consequent number of chairs needed for a specific year in a given area.

Estimating the student population over the next decade allows for a detailed analysis of trends in both Lombardy and the province of Mantova.

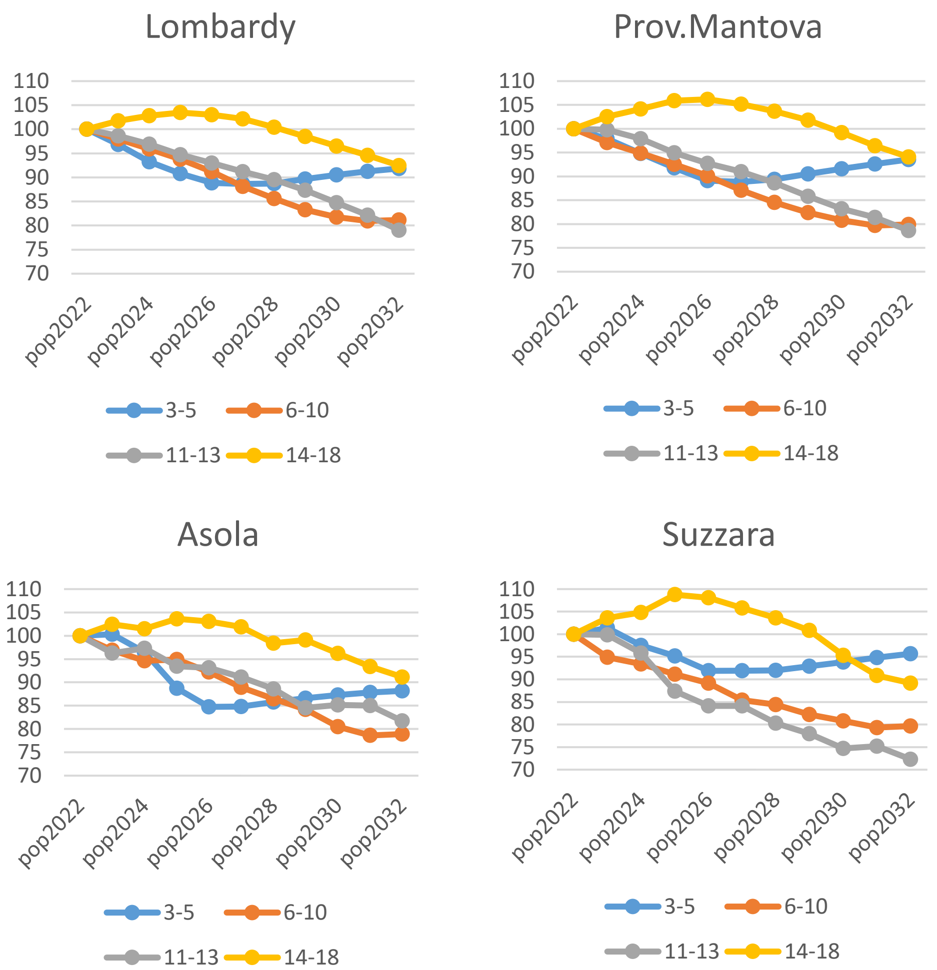
While the overall patterns in these regions are similar, there are notable differences. In Mantova, the decline in primary school students occurs slightly earlier than in Lombardy as a whole. Meanwhile, the growth in the Upper Secondary student population is more pronounced in Mantova, with the eventual decline delayed by a couple of years compared to the broader Lombardy context.

These regional and provincial trends, however, do not fully capture the important local variations that become apparent when examining specific school districts. Incorporating these territorial specificities into provincial and regional educational policies is critical. For instance, in the Asola district, a sharper decline in preschool enrollment is observed, while in Suzzara, the contraction of secondary school students is more prominent. However, Suzzara also experiences a notable short-term expansion in its secondary school population, surpassing the growth seen in both Asola and the broader Mantova territories (Fig. 1).

These localized variations emphasize the need for tailored policies that address the unique demographic shifts occurring within individual districts, ensuring that educational planning is responsive to the evolving needs of each area.

However, these trends should be analyzed beyond just numbers. It is essential to consider how local socioeconomic factors, migration patterns, and birth rates influence these shifts. For instance, declining student populations in some areas could signal broader demographic challenges such as aging populations or outward migration of younger families. Conversely, growth in certain student age groups, like Upper Secondary in Mantova, may necessitate further investment in schools, teachers, and training programs to ensure educational standards are maintained.

Figure 1 – *Variation in student population by age groups in Lombardy, Province of Mantova, district of Asola and district of Suzzara. Index numbers (2022=100).*



For planning purposes, the model is particularly useful as it can quantify, in terms of order of magnitude, the future population of specific years, as well as the number of classes/sections and places/chairs, with their variations for each school grade at different territorial levels. As an example, we report the estimates for the 2029/30 school year (Tables 1, 2 and 3). In this time span Lombardy will see a decrease of almost 161 thousand students and the province of Mantova of more than 6 thousand, with a relative variation of 11.7%. The relative contraction in the two districts considered is even more substantial. In the various territorial levels considered, the greatest decreases are observed in Primary and First grade Secondary schools.

Table 1 – *Forecast of student population in a.s. 2029/30 by age groups. Absolute variation (a.v.) and relative variation (r.v.).*

	Lombardy		Prov. Mantova		Distr. Asola		Distr. Suzzara	
	b.y.*	a.v. *(r.v.)*	b.y.*	a.v. *(r.v.)*	b.y.*	a.v. *(r.v.)*	b.y.*	a.v. *(r.v.)*
3-5 | Infancy	22,4752	-21,304 *(-9.5)*	9,237	-774 *(-8.4)*	1,157	-147 *(-12.7)*	1,155	-71 *(-6,1)*
6-10 | Primary	440,324	-80,463 *(-18.3)*	17,754	-3,410 *(-19.2)*	2,127	-415 *(-19.5)*	2,260	-434 *(-19.2)*
11-13 | Secondary I	294,531	-44,843 *(-15.2)*	11,866	-1,989 *(-16.8)*	1,414	-209 *(-14.8)*	1,614	-409 *(-25.3)*
14-18 | Secondary	412,268	-14,308 *(-3.5)*	14,805	-125 *(-0.8)*	1,797	-68 *(-3.8)*	1,919	-90 *(-4.7)*
Total	1,371,875	- *(-11.7)*	53,663	-6,299 *(-11.7)*	6,496	-840 *(-12.9)*	6,948	-1,004 *(-14.5)*

** Frequencies in the base years (=2022)*

Table 2 – *Forecast of classes/sections by age groups in Lombardy, Province of Mantova, district of Asola and district of Suzzara. Estimated of absolute variation.*

	Lombardy		Prov. Mantova		Distr. Asola		Distr. Suzzara	
	b.y.*	v.a.	b.y.*	v.a.	b.y.*	v.a.	b.y.*	v.a.
3-5 | Infancy	10,218	-969	410	-34	51	-7	51	-3
6-10 | Primary	22,085	-4,036	920	-177	110	-22	117	-23
11-13 | Secondary I	13,651	-2,078	545	-91	65	-10	74	-19
14-18 | Secondary	19,538	-678	733	-6	89	-3	95	-4
Total	65,491	-7,761	2,608	-309	316	-41	338	-49

** Frequencies in the base years (=2022)*

Table 3 – *Forecast of posts/chairs by age groups in Lombardy, Province of Mantova, district of Asola and district of Suzzara. Estimated of absolute variation.*

	Lombardy		Prov. Mantova		Distr. Asola		Distr. Suzzara	
	b.y.*	v.a. 2030	b.y.*	v.a.	b.y.*	v.a.	b.y.*	v.a.
3-5 | Infancy	16,980	-1,610	665	-56	83	-11	83	-5
6-10 | Primary	33,821	-6,180	1,237	-238	148	-29	157	-30
11-13 | Secondary	22,752	-3,464	908	-152	108	-16	123	-31
14-18 | Secondary	32,563	-1,130	1,222	-10	148	-6	158	-7
Total	106,116	-12,384	4,032	-456	488	-61	522	-74

** Frequencies in the base years (=2022)*

5. Conclusion and limitations of the study

The proposed statistical forecasting tool presents several key strengths. One of its primary advantages is its accessibility and practicality, as it relies on publicly available data and clear, easily understandable assumptions. This makes the model straightforward to implement, even for organizations with limited resources. Another notable strength is its reliability and methodological soundness. By using official data and established statistical methods, the model ensures that the forecasts are both robust and reliable. Additionally, the tool offers spatial granularity, allowing for detailed forecasts at both municipal and provincial levels of school autonomy. This capability supports targeted planning that can be adapted to the specific needs of each territory.

These attributes make the model a valuable resource for local and national school supply planning. This is especially relevant at the local level, where local authorities (municipalities and provinces) make many decisions regarding the management of school buildings. The introduction of solid forecasting elements concerning student population size and the consequent need for educational resources (teachers, classrooms, facilities) can rationalize and improve the efficiency of decisions that might otherwise be made erratically or based on partial considerations.

The current formulation of the model presents several limitations that should be addressed to improve its effectiveness as a tool for educational planning. One significant gap is the lack of insights into preferences regarding study directions at the upper secondary school level, such as high school, technical, vocational, and IeFP paths. While incorporating these preferences into a forecasting model is challenging, it is essential for decision-makers. A possible approach could be to combine demographic forecasts with trends in study path selection to better capture these dynamics. Another limitation involves the impact of citizenship and migratory background, as educational choices and course preferences are closely tied to these factors. Families of foreign origin, often concentrated in specific areas, have a notable influence on school behavior, birth rates, and migration patterns. Including elements related to immigrant populations in the forecasting model would provide a more comprehensive understanding of these influences. Additionally, while the demographic trends underlying the model—such as birth, death, and migration rates—are relatively stable in the short term, some school planning decisions, such as constructing new schools, require a longer-term perspective and are difficult to reverse. Therefore, the model's forecasts should not be seen as purely quantitative inputs but rather as tools to highlight an area's demographic and social characteristics and to facilitate continuous monitoring of developmental trends.

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