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# The economic benefit of implementing assisted reproductive technology within a national health system: insights from the Italian model

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## Abstract

**Background** Models evaluating both costs and economic benefits of assisted reproductive technology (ART) implementation are lacking. This constitutes a major limitation in the decision-making process of resource allocation. Herein, we aimed to estimate the economic and social impact of female infertility in Italy and examine the benefits generated by investment in ART from a national perspective.

**Methods** A retrospective cohort study was conducted using the Italian Hospital Discharge Records database to identify women aged 18–50 undergoing ART between 2014 and 2016 in Italy. Patients were followed for up to 36 months after the first ART complete cycle. Hospitalization costs were analyzed nationally, while outpatient care and drug consumption costs were assessed in a sub-analysis using administrative databases from LHM Umbria 2. A fiscal impact model was developed from a governmental perspective, projecting lifetime tax revenues and public expenditures associated with the ART birth cohort, including costs for healthcare, education, pensions, and social transfers. All future values were discounted at 3% in line with Italian economic evaluation guidelines.

**Results** A total of 33,713 women met the inclusion criteria. During the follow-up, 48.4% achieved pregnancy resulting in childbirth. The average hospital care cost per patient was €5,853, with a projected national expenditure of €337 million for ART management. Younger women (18–33 years) had the highest success rates (61.8%). Assuming 16,300 live births, the model estimated net fiscal benefits of €3.3 billion over the lifetime of these individuals, equivalent to €203,856 per live birth.

**Conclusion** This study highlights the economic and fiscal benefits of ART, emphasizing the need for policies promoting early access to treatment. ART investment represents a strategic approach to mitigate demographic decline, with each live birth substantially contributing to national fiscal stability.

## Key points

- Investing in Assisted Reproductive Technology (ART) within national health systems can generate significant economic returns, substantially exceeding initial healthcare expenditures.

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• Public funding of ART contributes positively to national economies by increasing future tax revenues and addressing demographic challenges related to declining fertility.

**Keywords** Infertility, Assisted reproductive technology, Medically assisted reproduction, Real world evidence, Italy, Economic burden

## Introduction

Infertility, as defined by the World Health Organization (WHO), “is a disease of the male or female reproductive system characterized by the failure to achieve a pregnancy after 12 months or more of regular unprotected sexual intercourse” [1, 2]. Infertility can be classified as primary, when a couple has never had children, or secondary, when a pregnancy has occurred in the past [3].

The WHO has estimated a global prevalence of lifetime infertility (defined as the experience of infertility, as defined by the WHO, at any point in a person’s reproductive life) at 17.5%. This estimate has been shown to vary across regions. Among global regions, the Western Pacific shows the highest estimated rates of lifetime infertility (23.2%). This is followed by the Americas (20.0%), Europe (16.5%), and, with the lowest prevalence, the African region (13.1%) [4, 5]. In most cases—around 85%—infertility can be traced to specific physiological disruptions or underlying medical conditions. Among the leading causes are issues with ovulation, male reproductive factors, and damage to the fallopian tubes [6].

Italy is facing a demographic emergency; the country is characterized by the lowest fertility rates among high-income nations, with a Total Fertility Rate (TFR) of 1.24 in 2020, substantially below the replacement level (2.1). At the same time, Italy records the highest mean maternal age at first birth (31.4) and one of the highest paternal ages [7]. These demographic patterns reflect broader sociocultural dynamics, such as delayed childbearing linked to education, career, and structural barriers to work-family balance.

To address infertility, many couples turn to assisted reproductive technology (ART). This can range from less invasive approaches like intrauterine insemination (IUI) to more advanced procedures involving fertilization outside the body, such as in vitro fertilization (IVF) and intracytoplasmic sperm injection (ICSI) [4]. The type of ART to be adopted depends on several factors, including the age of the female patient, the time spent seeking pregnancy naturally, the etiology of infertility and the will of the couple.

Infertility treatment is expensive. High costs limit access to ART, especially in countries where these treatments are not publicly funded or where not all residents have access to reimbursement. In the literature, few studies have attempted to estimate the costs associated with

infertility treatment in women. Specifically, the study by Matorras et al. investigated the costs of IVF treatments in eight countries, reporting a total cost per treatment cycle of €8,127 in Spain, €8,776 in Norway, €9,623 in the UK, €6,051 in Germany, €6,748 in Denmark, €4,245 in South Korea, €4,108 in Australia, and €12,314 in New Zealand [8]. In 2018, a study conducted in Germany reported a cost of €4,000 per IVF treatment cycle, while another study in Spain estimated a total cost ranging from €3,500 to €5,500 [9, 10].

In the context of ART, the cost per live birth depends on many factors. As can be easily understood, for example, obtaining a live birth in a population with a poor prognosis is much more expensive than in a population with a good prognosis [11]. Furthermore, it has been demonstrated that clinical strategies favoring frozen-thawed embryo transfer (FET) determine a reduction in the cost per live birth with respect to fresh embryo transfer [12].

On the other hand, ART may offer notable economic advantages. Preliminary findings indicate that public investment in fertility treatments can yield returns over time, as children born through these interventions eventually contribute to the labor force and generate future tax revenues for the state [13]. In Europe, several studies have investigated the economic benefits of infertility treatments. Specifically, in Spain [14], Denmark [15], Sweden [16], and Greece [17], it has been demonstrated that each birth resulting from assisted reproduction generates a net fiscal benefit for the state over the individual’s lifetime.

However, these studies have primarily focused on quantifying the economic benefits, without integrating an assessment of the direct healthcare costs associated with ART. To date, models that provide a comprehensive, net estimate of the economic impact of ART—considering both the public expenditure for treatment and the fiscal return generated by births—are still lacking, especially in the Italian context. This constitutes a major limitation in the decision-making process of resource allocation. Herein, we studied the Italian scenario where infertility affects approximately 15% of couples of reproductive age and where approximately 10,000 homologous IVF/ICSI cycles per million women of childbearing age are performed every year. Specifically, our aim was to assess the economic and social impact of female infertility in Italy

and examine the benefits generated by investment in ART from a national perspective.

### Data sources

This analysis draws on data from Italy's national Health Information System (HIS), which covers the entire population (about 60 million people), and from the HIS of the Local Health Unit (LHU) Umbria 2, serving around 380,000 residents.

### Italian HIS

Italy's HIS captures comprehensive information on all hospital discharges—both inpatient admissions and day-hospital stays—from public and accredited private healthcare facilities. Each record includes an anonymous patient identifier and contains demographic data (such as age, sex, and place of residence) alongside clinical details, including a main diagnosis and up to five secondary diagnoses and procedures, as well as the assigned Diagnosis-Related Group (DRG). The data used in this study spans the period from 2010 to 2019.

### LHU Umbria2 HIS

The HIS for LHU Umbria 2 systematically gathers patient-level data on hospitalizations, outpatient visits, drug prescriptions, and laboratory tests for individuals listed in the Regional Health Care Assistance Registry. Each patient is tracked using an anonymous identifier, enabling exact matching across different data sources. The available dataset covers the years from 2014 to 2022.

### Methods

This study applied a multi-level analytical approach to quantify the economic and fiscal impact of ART in Italy. The analysis was conducted in three stages: (i) a national-level assessment of hospitalizations and related costs using the Italian Hospital Discharge Records database; (ii) a regional analysis within LHU Umbria 2 to evaluate drug consumption and outpatient care; and (iii) a fiscal impact model projecting the lifetime economic contribution of the ART birth cohort to the Italian government. The model considered both direct healthcare costs (hospitalizations, drugs, outpatient visits) and public expenditures, including healthcare, education, pensions, and social transfers, as well as lifetime gross and net tax revenues. All economic values were adjusted for inflation and discounted at 3% following national health economic evaluation guidelines.

### National analysis

A retrospective cohort was built, by selecting all women of age 18–50 resident in Italy hospitalized with a procedure of ART between 2014 and 2016.

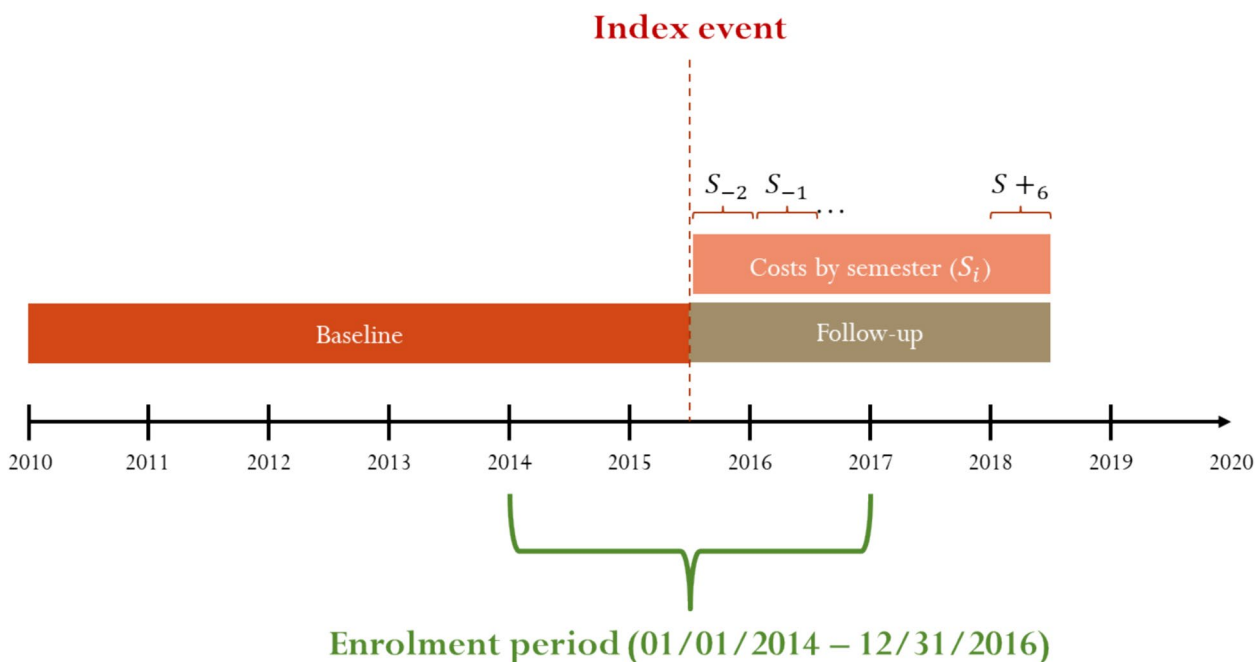
Hospital admissions related to a ART procedure were identified by the presence of one of the following conditions:

- A hospitalization where artificial insemination was coded as the primary or secondary procedure (ICD-9-CM 69.92, “Artificial insemination”),
- A hospitalization with Diagnosis Related Group (DRG) 365 (“Other female reproductive system operating room procedures”, used as a proxy for embryo transfer), preceded in the previous five months by a hospitalization with DRG 359 (“uterine & adnexa procedure for non-malignancy without complications, comorbidities”, used as a proxy for oocyte retrieval or “pick-up”). The presence of both DRGs associated with the same patient ensures that the two specific procedures (i.e., oocyte retrieval and embryo transfer) were indeed performed. In other words, there are no other procedures included within these two DRGs that could be carried out in that sequence (DRG 359 followed by DRG 365) and within a five-month period on the same patient.

The analysis focused exclusively on incident cases by first removing from the cohort all women who had been hospitalized for ART between 2010 and 2013. Among those who accessed ART during the enrollment period, only the earliest hospitalization was retained and treated as the index event, even if multiple admissions were recorded (Fig. 1). All patients were followed for a maximum of 3 years, up until the 31st of December 2019. All women who either died or were diagnosed with a malignant neoplasm (ICD-9-CM 140–208) during follow-up were excluded from the study.

To estimate the number of pregnancies resulting in childbirth among women treated with ART, we identified hospitalizations coded with a childbirth-related DRG, as listed in Supplemental Table S1. The conception date was estimated by subtracting 280 days from the hospitalization date. Women were considered to have conceived and delivered during the study period if this estimated conception date occurred within the 36-month follow-up window. Once a pregnancy was identified, the patient was censored from further follow-up analyses.

Expenditure related to hospital admissions, stratified by event (childbirth, other causes) was estimated by semester of follow-up (1st to 6th). The number of pregnancies by month of follow-up was reported, as well as the distribution of patients by number of transfer procedures after the index event. Results were stratified by age at index event (18–33, 34–38, 39–50).



**Fig. 1** Enrolment scheme for the national analysis

**LHU Umbria 2 analysis**

The same approach was applied in the analysis on LHU Umbria 2. In this analysis, patients were enrolled between January 2017 and December 2019 and the baseline period was 2014–2016, enrolment scheme for this analysis is reported in Supplemental Material (Figure S1). Patients were followed for 3 years, up until the 31st of December 2022. The same outcomes obtained for the national analysis were retrieved in this case as well; the only difference was in the cost estimation, which, thanks to the linkage of all the databases available for LHU Umbria 2, focused on the consumption of drug consumptions and outpatient visits.

**Predictive model**

Mean costs per patient obtained from LHU Umbria 2 analysis on drugs and outpatient visits were summed to the mean costs per patient related to hospital admissions from the national analysis, to estimate the overall expenditure. The obtained value was multiplied by the number of women incident cases of ART from the national analysis, to estimate the economic burden of infertility management in Italy in terms of direct healthcare costs.

**Fiscal Effect and Economic consequences**

To project the lifetime fiscal value of the ART birth cohort, a governmental perspective modeling framework was developed capturing age-specific financial

transactions with the Italian government. This consisted of applying age-specific wage data applied to the Italian tax wedge for estimating direct taxes. Estimates for lifetime transfers received at various stages of life were included and deducted from lifetime taxes paid to derive the net tax revenue per individuals. The analysis described here is comparable to previously described frameworks for estimating the lifetime tax contributions of ART children [13] and is consistent with the generational accounting framework applied in Italy for estimating lifetime net taxes [18].

The framework was constructed using age-specific data on wages, employment activity and adjusted using the Italian life tables obtained from the Italian National Institute of Statistics (ISTAT) [19]. The annual earnings by age were then applied to the tax wedge which includes both the taxes and social insurances paid by individual workers including the social insurances paid by employer [20]. Wages were adjusted based on average wage growth over the period 2000–2015 using data from ISTAT [21]. Indirect taxes were estimate by age based on disposable incomes and applying the VAT rate.

To project age-specific lifetime costs of individuals to the Italian government, we quantified per person spending on education (pre-primary, primary, secondary and tertiary education), healthcare spending per person, pension costs, and data obtained from the Banca d’Italia Household Survey which details annual transfers received per household by age [22]. All values in the

model were adjusted for inflation and discounted at 3% as per Italian guidelines for economic evaluation [23]. A full list of model input parameters is detailed in the Supplemental Material (Table S2-7).

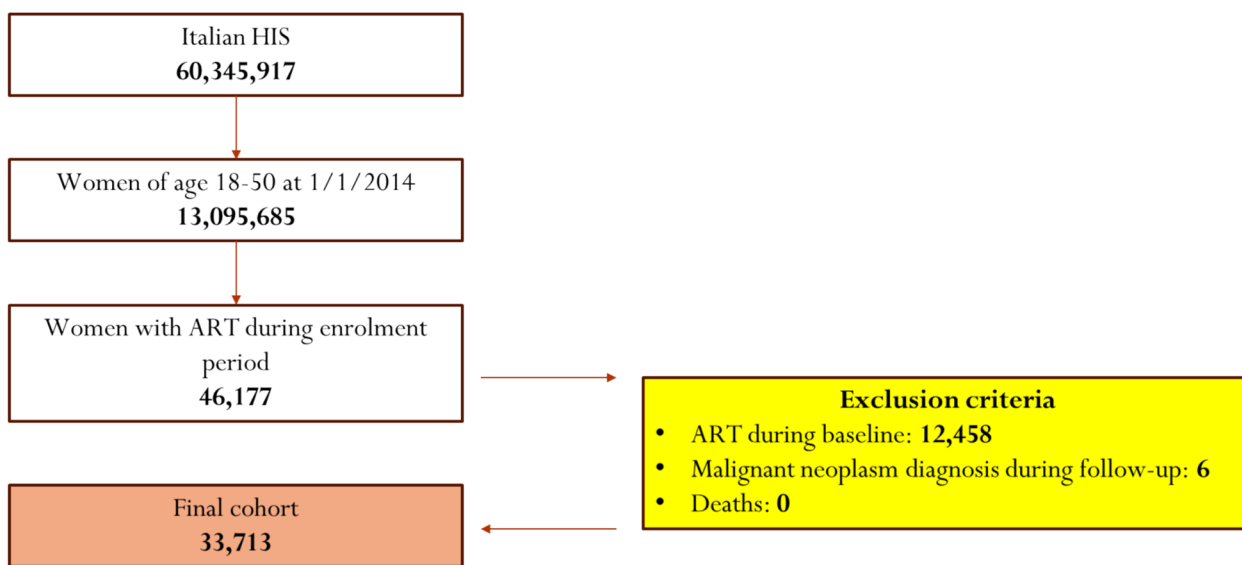
**Results**

**National analysis**

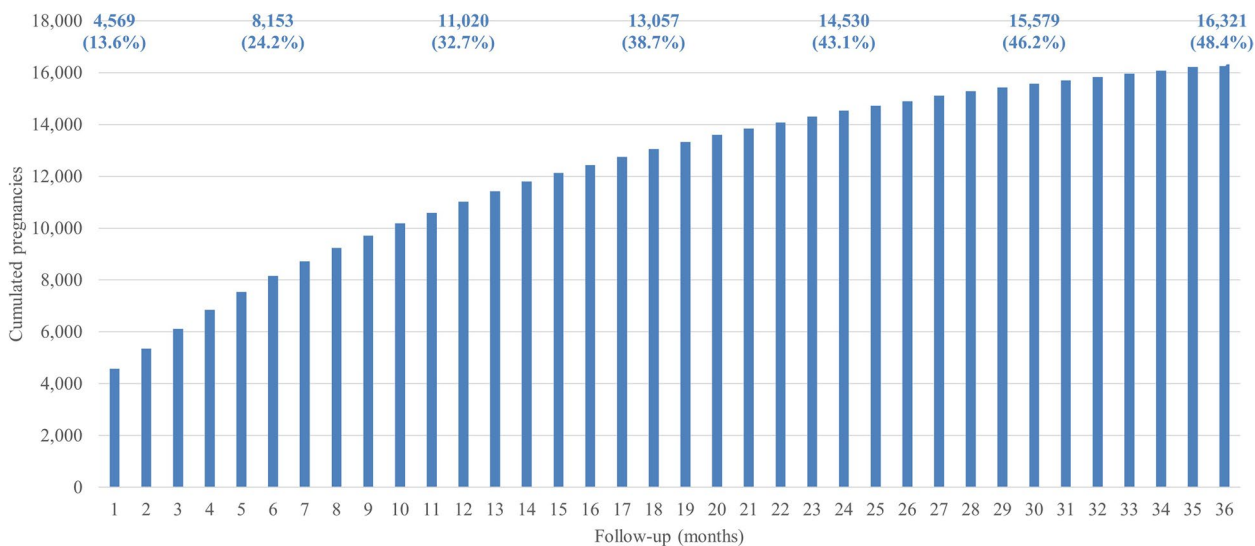
In Italy, between 2014 and 2016, 46,177 women experienced a hospital admission for artificial insemination. Of these, 12,458 were excluded due to a hospital admission for artificial insemination observed during 2010–2013 while 6 patients were excluded due to a

diagnosis of malignant neoplasm during follow-up. No deaths were reported during follow-up. Women that met inclusion criteria were 33,713 (Fig. 2).

During the follow-up period, 16,321 pregnancies resulting in childbirth were recorded (48.4% of the total enrolled patients). Of these, 4,569 (13.6%) were observed within the first month of follow-up, indicating the success rate of the first artificial insemination procedure. The percentage of patients with a pregnancy after one year of follow-up was 32.7%, and after two years, it was 43.1% (Fig. 3).



**Fig. 2** Flowchart of cohort selection, Italy. HIS Health Information System. ART Assisted Reproductive Technology



**Fig. 3** Monthly cumulated distribution of pregnancies during follow-up in Italy

Patients of age 18–33 at first ART procedure were 8,416 (25.0%), while the largest category was found to be patients aged 34–38 (12,969, 38.5%), followed by those aged 39–50 (12,328, 36.5%). As expected, the cumulated rate of pregnancies during the 3-year follow-up was higher in age group 18–33 (61.8%), followed by age group 34–38 (53.1%) and 39–50 (34.3%). The same trend was observed during 1st month of follow-up, with rates of pregnancies equal to 18.9%, 15.8% and 7.5%, respectively (Table 1).

Overall, 60.0% of patients (20,215) had no further transfers procedures after the index event (Table 2). Considering 13.6% of patients exited follow-up due to the success of ART during index event, this means that 46.4% of patients did not attempt a second artificial insemination procedure following the first unsuccessful attempt. A negative correlation was observed between the rate of patients with 0 transfers during follow-up and age (65.3% in 39–50 group vs 55.2% in 18–33). In total, 18.3% of patients had 1 more transfer during follow-up, patients with 2 transfers were 10.8% while 10.9% had 2 or more transfer procedures.

On average, during follow-up cost per patient was equal to €5,853 (Fig. 4); of these, €1,007 was due to childbirth, while expense for other hospital admissions was €4,846. The expenditure related to childbirth was zero during the first semester of follow-up, reaching its peak during the second semester (€559) and progressively decreasing in the subsequent semesters (€193 during the sixth). A negative trend was also observed in the expenditure for hospitalizations due to causes other than childbirth, with the highest value recorded in the first semester (€2,453), partly due to the inclusion of the index event during this

period. Only 19,183 subjects contributed to the estimate of costs during the last semester of follow-up.

Mean cost per patient was higher in age group 18–33, both for childbirth (mainly due to the higher percentage of women conceiving) and other hospitalizations, while lowest expense was observed in 39–50 category (€716 for childbirth, €4,429 for other hospital admissions, Table 3). Trends were consistent across age groups, both in terms of direction and magnitude.

**LHU Umbria 2 analysis**

In LHU Umbria 2, between 2019 and 2021, women with a hospital admission for artificial insemination were 72. Of these, 18 were excluded due to a record of the same procedure during 2014–2018, no deaths or diagnoses of malignant neoplasm were reported during follow-up. Women that met inclusion criteria were 54 (flowchart in Supplemental material, Figure S2). Pregnancy was estimated in 9 women (16.7%) during the first month of follow-up and 31 women (57.4%) at the end of the 3-year period, 9 patients had another embryo transfer procedure during follow-up and 3 patients had 2 or more procedures (Supplemental material, Figure S3).

On average, expenditure per patient during the 3-year follow-up was €751 for drug consumption and €450 for outpatient visits. Costs for drug consumptions were higher during the first semester of follow-up (€488, Fig. 5), with a significant decrease between the third and fourth semester. A similar trend was observed for outpatient visits, although the second semester was the one associated with the higher expenditure (€201). Overall, a higher variability in the trend of costs by semester was observed, probably due to the small size of the cohort.

**Table 1** Cumulated distribution of pregnancies during follow-up by age group in Italy

Age group	Patients	1 st month	1 st semester	2nd semester	3rd semester	4th semester	5th semester	6th semester
18–33	8,416	1,594 (18.9%)	2,777 (33.0%)	3,643 (43.3%)	4,252 (50.5%)	4,687 (55.7%)	4,996 (59.4%)	5,204 (61.8%)
34–38	12,969	2,049 (15.8%)	3,561 (27.5%)	4,802 (37.0%)	5,598 (43.2%)	6,184 (47.7%)	6,601 (50.9%)	6,890 (53.1%)
39–50	12,328	926 (7.5%)	1,815 (14.7%)	2,575 (20.9%)	3,207 (26.0%)	3,659 (29.7%)	3,982 (32.3%)	4,227 (34.3%)
Total	33,713	4,569 (13.6%)	8,153 (24.2%)	11,020 (32.7%)	13,057 (38.7%)	14,530 (43.1%)	15,579 (46.2%)	16,321 (48.4%)

**Table 2** Distribution of transfer procedures during follow-up (index event excluded) in Italy, by age group

Age group	Patients	Transfer procedures during follow-up (index event excluded)					
		0	1	2	3	4	≥ 5
18–33	8,416	4,647 (55.2%)	1,624 (19.3%)	1,009 (12.0%)	557 (6.6%)	316 (3.8%)	263 (3.1%)
34–38	12,969	7,516 (58.0%)	2,339 (18.0%)	1,516 (11.7%)	761 (5.9%)	457 (3.5%)	380 (2.9%)
39–50	12,328	8,052 (65.3%)	2,190 (17.8%)	1,106 (9.0%)	552 (4.5%)	254 (2.1%)	174 (1.4%)
Total	33,713	20,215 (60.0%)	6,153 (18.3%)	3,631 (10.8%)	1,870 (5.5%)	1,027 (3.0%)	817 (2.4%)

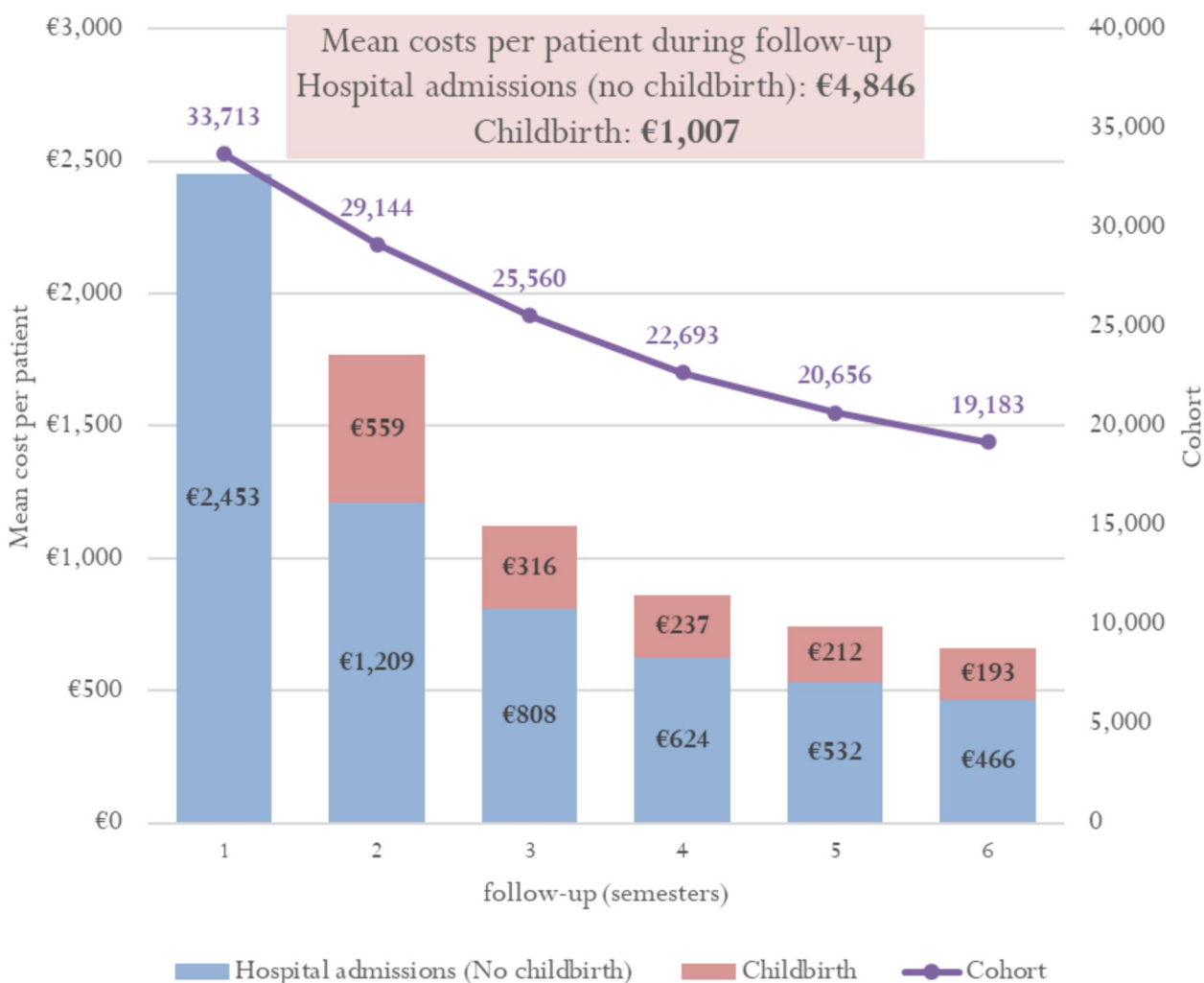
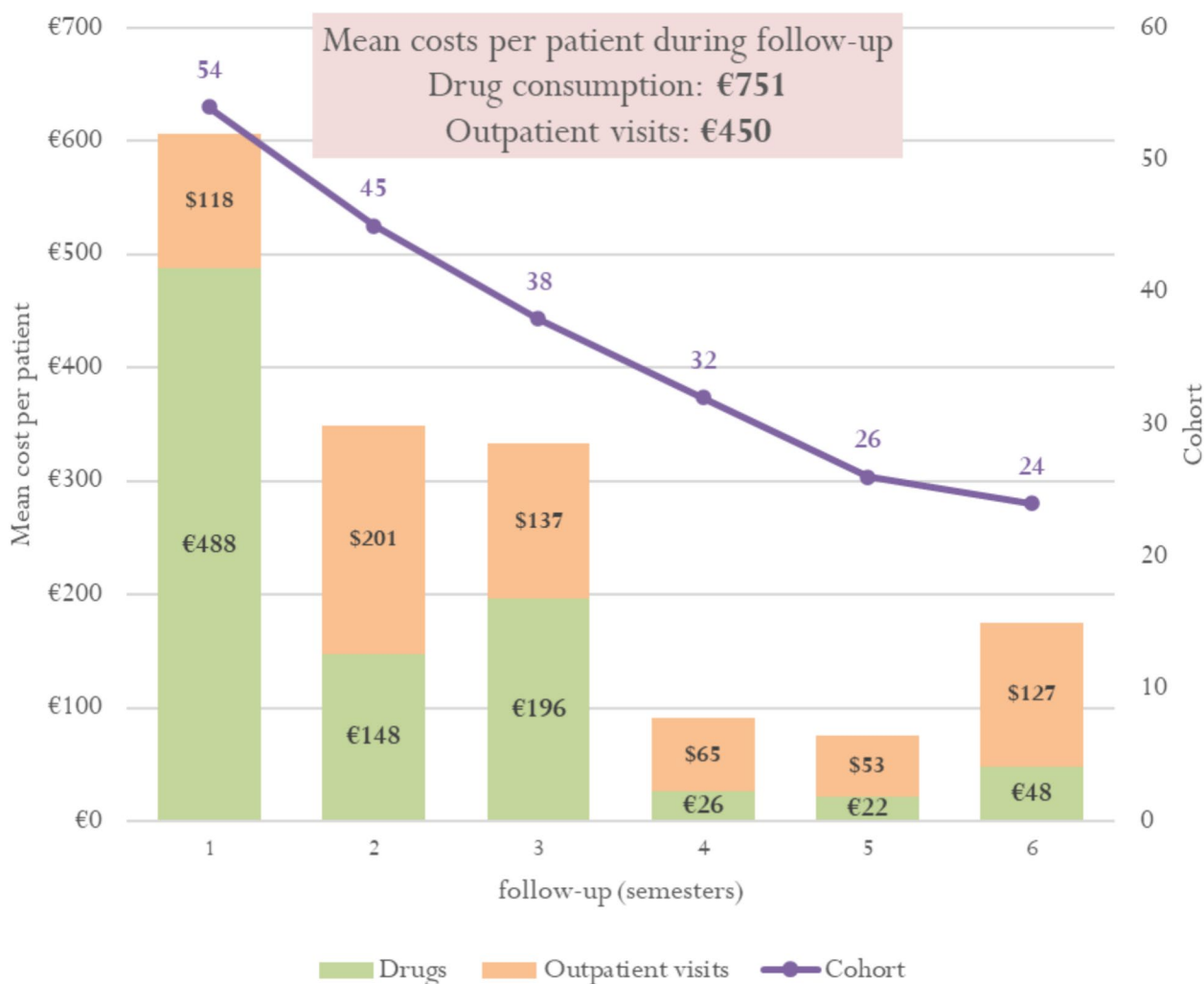


Fig. 4 Mean cost per patient for hospital admissions in Italy, by semester of follow-up

Table 3 Mean cost per patient for hospital admissions in Italy, by semester of follow-up and age group

Age group	Patients	Voice of cost	Semester of follow-up						Total follow-up
			1st	2nd	3rd	4th	5th	6th	
18–33	8,416	HAs (no childbirth)	€2,536	€1,421	€1,006	€862	€798	€794	€5,158
		Childbirth	€0	€857	€443	€331	€336	€331	€1,275
34–38	12,969	HAs (no childbirth)	€2,458	€1,335	€930	€733	€643	€568	€5,041
		Childbirth	€0	€676	€369	€266	€238	€223	€1,109
39–50	12,328	HAs (no childbirth)	€2,391	€982	€608	€428	€331	€253	€4,429
		Childbirth	€0	€294	€210	€169	€138	€114	€716
Total	33,713	HAs (no childbirth)	€2,453	€1,209	€808	€624	€532	€466	€4,846
		Childbirth	€0	€559	€316	€237	€212	€193	€1,007

HAs Hospital Admissions



**Fig. 5** Mean cost per patient for drug consumption and outpatient visits in LHU Umbria 2, by semester of follow-up

**Predictive model**

The model projected a total economic burden in Italy of €337 million for managing approximately 33,000 patients treated with ART (with 31% attributed to drug acquisition, 32% to outpatient visits, and 47% to hospitalizations, Fig. 6). Assuming this investment results in approximately 16,300 live births, the estimated net tax benefits over the lifetime of these individuals would amount to €3.3 billion. Based on investment costs of €337 million in relation to the fiscal gains from the ART birth cohort, an approximate ninefold return on investment is achieved for every €1 invested.

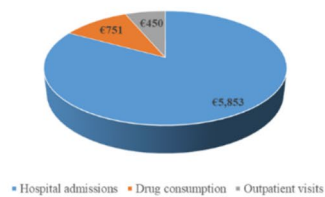
**Discussion**

The objective of this study was to assess the economic and social impact of female infertility in Italy and examine the benefits generated by investment in ART from a national perspective. Infertility represents one of the

most pressing healthcare challenges of our time, not only for its impact on couples but also for its social and economic implications, particularly in relation to demographic decline [14]. To our knowledge, this study is the first one providing a detailed analysis of the Italian context, addressing epidemiological, economic, and organizational aspects of ART using real-world data covering the whole country.

In Italy, approximately 15% of couples experience infertility issues, a prevalence that mirrors global trends but also reflects the country’s demographic characteristics, such as the increasing average age of women at first childbirth [24, 25]. In Italy, between 2014 and 2016, on average around 70,000 couples were treated with artificial insemination each year, with a rate of success in terms of childbirth equal to 14.0% [26]. Although the size of the cohort we identified is smaller than the aforementioned figure, the success rate estimated in our analysis during

Mean health expenditure per patient



Net fiscal benefits (lifetime) per live birth



33,700 treated women  
16,700 live births

**Direct health costs**  
**€238 Million**  
**Net fiscal benefit**  
**€3.3 Billion**

Fig. 6 Costs and fiscal benefits' analysis of ART treatment in Italy

the first month of follow-up is almost identical to the one reported from the Italian Ministry of Health. Therefore, we can conclude that the sample of patients analyzed in our study can be considered representative of the national study population.

The study offered critical insights into the outcomes of ART procedures. Among the 33,713 women included in the analysis, 48.4% achieved pregnancy resulting in childbirth during the three-year follow-up period, with younger women (18–33 years) demonstrating higher success rates (61.8%) compared to older age groups. This reflects the significant influence of maternal age on fertility outcomes, underscoring the importance of timely access to reproductive treatments [26, 27]. Although costs during follow-up were higher in younger patients, the higher success rate of ART procedures observed in this group suggests that policies should promote early access to artificial insemination where necessary, to achieve better outcomes.

The economic burden of infertility management is another critical dimension explored in the study. The average cost per patient during the 3-year follow-up was €7,054, with a significant portion allocated to hospital admissions unrelated to childbirth. A study with a similar approach and the same follow-up was conducted in France on data retrieved from administrative databases [28]. Comparable costs to those we observed were estimated for the first two semesters of follow-up. However, from the third semester onward, our analysis highlights a clear and progressive reduction in expenditures.

Additionally, in the French study, the primary cost driver was related to medications. This difference may be attributable to the distinct inclusion criteria used in the two studies.

The study aligns with existing literature demonstrating the fiscal benefits of each live birth resulting from ART. In Italy, it is estimated that every live birth could generate a net lifetime tax contribution of €203,856. This highlights the potential of ART not only as a healthcare intervention but also as a tool for mitigating the socioeconomic impact of population aging and workforce reduction. Several studies estimated the lifetime net fiscal benefit of an individual born from ART across different countries, with values ranging from 61,428 United States Dollars (USD) in Brazil to €154,100 in Denmark [15, 16, 29, 30]. Although the estimated benefit in our study is higher than that reported in other studies in the literature, it is not significantly different from the estimates obtained in a study conducted by the Bank of Italy [31]. That study calculated a value of net lifetime taxes of €184,191 for generations born before 2006, which is projected to exceed €300,000 for future generations. The comparability of our net tax projections suggest our framework is consistent with that used by the Bank of Italy for assessing generational policies.

Some limitations should be considered when interpreting the results. First, the analysis relies on administrative databases, which, despite their extensive coverage, may have limitations in data granularity and accuracy. Data from the Italian Ministry of Health report a higher

number of transfer procedures (around 70,000) along the study period, with respect to our estimates. Yet, the rates of success are consistent with our estimates, both overall (14.0% vs 13.6%) and when stratifying the analysis by age category [26].

Secondly, to define a 3-year follow-up period, the national cohort selection was carried out between 2014 and 2016, thereby foregoing the use of more recent data. However, the decision to analyze such an extended follow-up period was driven by the aim to provide a more detailed examination of the costs incurred by the National Health Service (SSN) and to obtain a cumulative estimate of the number of pregnancies resulting in childbirth following a cycle of ART treatments. This approach addresses a significant gap in official Italian ART registry data, which only report the success rate of embryo transfers without offering a comprehensive picture of medium- to long-term outcomes. By adopting this methodology, the study delivers valuable insights into the broader implications of ART treatments over time, particularly in terms of cumulative success rates and economic impact.

Third, only incident ART cases, identified as women with no ART-related hospitalizations in the years preceding the enrollment period were included in the study. While this allows for a consistent cost estimation starting from the first treatment cycle, it may result in a higher proportion of first-time ART users, who generally show higher success rates than those undergoing repeated cycles after previous failures. However, it should be noted that the success rate estimated in our study (32.7%) is consistent with national data reported by the Italian ART Registry, which considers all ART procedures performed in Italy and estimated a cumulative pregnancy rate of 31.7% in 2022. With regard to the success rate of ART, another limitation of the present study is the inability to definitively confirm that all deliveries recorded during the follow-up period were the direct result of ART procedures. It is well established that a proportion of women may achieve spontaneous pregnancies following failed ART attempts. To minimize the impact of this potential source of bias, the follow-up period was deliberately limited to a maximum of three years from the index ART procedure. This timeframe was chosen as it represents a reasonable window in which to capture ART-related outcomes, while reducing the likelihood that pregnancies unrelated to ART are misclassified as treatment successes.

Fourth, while hospitalization costs were estimated using national-level data, drug consumption and outpatient care costs were derived from administrative data of LHU Umbria 2, which covers approximately 0.7% of the Italian population. Although this represents a limitation

in terms of external validity, the demographic characteristics of the LHU Umbria 2 population, particularly in terms of age distribution, are comparable to national figures [32]. Therefore, the potential bias introduced by using these regional data for cost estimates is expected to be limited.

Fifth, it should be noted that the estimated follow-up costs primarily reflect healthcare resource consumption directly related to the infertility management pathway, including ART-specific pharmacological treatments, specialist visits, and hospital admissions. While it is possible that a portion of these costs may be unrelated to ART and represent general healthcare expenses that individuals would incur regardless, this component is expected to be marginal. The majority of the resource consumption captured in this analysis is inherently linked to the decision to undergo ART and would likely not have occurred in its absence. Nevertheless, this aspect should be considered a limitation of the study.

Sixth, according to the most recent data from the Italian National Registry of ART, 31% of ART cycles are performed in public facilities, 26% in privately owned but publicly accredited centers, and the remaining 43% in fully private (non-accredited) centers [33]. In the Italian healthcare system, accredited private providers operate under formal agreements with the SSN, enabling the delivery of services reimbursed through public funding mechanisms. In contrast, services delivered in fully private centers are entirely financed out-of-pocket by patients, with no entitlement to public reimbursement. Consequently, both public and accredited private centers apply DRG codes to ART procedures as part of the standardized reimbursement and reporting framework. Fully private centers, however, are not integrated into this system, and procedures performed therein are not associated with DRG codes. As a result, the DRG-based identification strategy employed in this study inherently excludes ART cycles conducted in non-accredited private facilities. This limitation should be taken into account when interpreting the generalizability of the findings, particularly with regard to cost estimations and considerations of equitable access to care within the broader healthcare system.

Finally, the study focused on comparing direct healthcare costs with net financial benefits, without taking into account other dimensions of the burden of infertility, such as indirect costs or the consequences infertility has on patients' mental health, as well as effects on their social and professional lives. Several studies have demonstrated that infertility constitutes a major life crisis, often associated with feelings of loss, isolation, anger, anxiety, depression, and reduced self-esteem, with up to 40% of women experiencing a diagnosable psychiatric condition,

most commonly anxiety or depression. [34]. The psychological distress linked to infertility may also translate into impaired work performance, withdrawal from social and professional settings, and increased absenteeism. While a causal relationship between mental health and infertility remains debated, there is consistent evidence that emotional suffering, exacerbated by repeated treatment failures, contributes to reduced wellbeing and diminished participation in daily life, including occupational activities [35].

## Conclusion

This study provides valuable insights into the economic and social impact of infertility and ART in Italy. The findings emphasize the significant burden of infertility on the healthcare system and highlight the effectiveness of ART in addressing this challenge. By demonstrating that younger patients achieve higher success rates and better outcomes, the study supports policies that encourage timely access to ART procedures to optimize results.

Despite the costs of care, when the benefits of ART are viewed in the context of public accounts, we demonstrate that each live birth generates substantial net lifetime tax contribution, reinforcing the importance of continued investment in ART as a strategic healthcare policy. These benefits extend beyond individual patients, contributing to mitigating the broader socioeconomic challenges associated with declining fertility rates and population aging. In addition to quantifying direct healthcare costs, this study introduces an integrated perspective by combining real-world data with a fiscal modeling framework, providing, for the first time in Italy, an estimate of the long-term economic return of ART. This dual-level approach offers policymakers a more complete understanding of the relationship between ART-related public investment and its potential to generate measurable benefits for society and the economy. On the other hand, evidence from the Italian context indicates that maternity often negatively affects women's labor market outcomes: many mothers reduce their working hours or leave the labor market altogether, experiencing income losses not typically faced by fathers. In addition, firms may respond to women's resignations after childbirth by increasing the hiring of women of childbearing age, but predominantly through temporary contracts, leading to reduced job stability for this group [36].

Future research should aim to provide an even more comprehensive assessment of the economic, social, and health impacts of infertility and ART. In particular, studies should explore the indirect costs associated with mental health consequences, productivity loss, and gender inequalities in the labor market, as well as the long-term well-being and social integration of ART-conceived

individuals. Such evidence would support more holistic, equitable, and sustainable reproductive health policies.

## Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s13561-025-00672-1>.

Supplementary Material 1.

Supplementary Material 2.

## Conflict of interest

The authors declare that they have no competing interests.

## Role of the funder/sponsor

The funder had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

## JEL classification

I11.

## Authors' contributions

All authors contributed to the study conception. AM, MS MC and AB developed the study design. MS and MC conducted the statistical analysis and derived the analytical results. The first draft of the manuscript was written by MS, GG, and MC and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

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## Data availability

No datasets were generated or analysed during the current study.

## Declarations

### Competing interests

The authors declare no competing interests.

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