2008 financial crisis vs 2020 economic fallout: how COVID-19 might influence fertility treatment and live births

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Abstract

Research Question: The economic and reproductive medicine response to the COVID-19 pandemic in the United States has reduced the affordability and accessibility of fertility care. We sought to determine the impact of the 2008 financial recession and the COVID-19 recession on fertility treatments and cumulative live-births.

Methods: We examined annual US natality, CDC IVF cycle activity and live birth data from 1999 to 2018 encompassing 3,286,349 treatment cycles, to estimate the age-stratified reduction in IVF cycles undertaken after the 2008 financial recession, with forward quantitative modelling of IVF cycle activity and cumulative live-births for 2020 to 2023.

Results: The financial recession of 2008 caused a four-year plateau in fertility treatments with a predicted 53,026 (95% CI 49,581 to 56,471) fewer IVF cycles and 16,872 (95% CI 16,713 to 17,031) fewer live births. A similar scale of economic recession would cause 67,386 (95% CI: 61,686 to 73,086) fewer IVF cycles between 2020 and 2023, with women younger than 35 years overall undertaking 22,504 (95% CI 14,320 to 30,690) fewer cycles, as compared to 4,445 (95% CI 3,144 to 5,749) fewer cycles in women over the age of 40 years. This equates to overall 25,143 (95% CI: 22,408 to 27,877) fewer predicted live-births from IVF, of which only 490 (95% CI 381 to 601) are anticipated to occur in women over the age of 40 years.

Conclusions: The COVID-19 recession could have a profound impact on US IVF live-birth rates in young women, further aggravating pre-existing declines in total fertility rates.

Keywords: economic recession, IVF, natality, live-births

Introduction

Affordability and availability of treatment are two important factors affecting a couple's decision to pursue *in vitro* fertilization (IVF)(Chambers *et al.* 2014, Chambers *et al.* 2012, Chambers *et al.* 2009, Connolly *et al.* 2009, Gromski *et al.* 2021, Smith *et al.* 2020). The emergence of COVID-19 as a risk to public health, and the resulting economic impact, affects both the affordability and availability of treatment. On March 17, 2020, the American Society for Reproductive Medicine (ASRM) recommended suspension of initiation of IVF treatments (ASRM 2020). At least 85% of IVF clinics followed the recommendations and shut down provision of routine care. On April 24, 2020, the ASRM Task Force recommended "gradually and judiciously resuming the delivery of reproductive care", with sequential updates reiterating this position given the dynamic situation (ASRM 2020).

Prior to the emergence of SARS-CoV-2, the US unemployment rate was at a historic low of 3.7% (5.7 million), and the economy at a peak (National Bureau of Economic Research 2020). With the onset of the COVID-19 pandemic, there was a dramatic rise in temporary unemployment peaking at 23.1 million in April 2020. However, despite a gradual decline to 17.8 million by June 2020, this has been accompanied by a rise in the number of permanent job losses to 2.9 million (Bureau of Labour Statistics; July 2nd, 2020). In the developed world there is a pro-cyclical relationship between economic growth and fertility, and in times of economic recession the birth rate drops (Sobotka *et al.* 2011). This was most recently observed after the 2008 financial crisis, where US birth rates declined and an estimated 2.3 million fewer births occurred between 2008 and 2013 (Johnson 2014). Clearly, economic hardship affects the affordability of having children and the decision to postpone is a potentially viable option for young women who have a longer fertility horizon (Sobotka *et al.* 2011). For couples considering IVF, postponement incurs the penalty of an age-related declines in success (Smith *et al.* 2015), while economic hardship additionally affects the affordability of treatment.

Reassuringly, the COVID-19 related temporary closure of IVF units and accompanying treatment delays is anticipated to have limited impact on live-birth rates (Rasmussen and Jamieson 2020). However, the impact of COVID-19 economic recession on IVF live births is unknown. Indeed, we are not aware of any prior publications regarding the impact of economic recessions on the use of IVF. COVID-19 additionally carries a direct health effect, fear of transmission, and fear of the unknown regarding pregnancy during a pandemic.

Despite the potentially substantial differences between the 2008 financial recession and COVID-19 pandemic, recent repeat survey data has confirmed the strong similarities on women's reproductive health, with similar proportions of women shifting their fertility preferences in favour of delaying childbearing or having fewer children, similar rates of contraceptive use and similar proportions of women reporting increased worry about affordability of birth control (Lindberg *et al.* 2020). Furthermore, there has been no evidence of a contrary "baby boom" due to the widespread societal changes, and several states have already reported a reduction in births in January 2021 (Kekatos 2020, State Health Departments 2020). The aim of this study is to examine the effect of the 2008 recession on IVF cycles and predict what impact the COVID-19 related economic recession and additional impact of clinic closures will have on the number of IVF cycles and live-births in the US.

Methods

Data sources

The Fertility Clinic Success Rate and Certification Act of 1992 requires that all assisted reproductive technology (ART) cycles performed in the United States are reported to the Centers for Disease Control and Prevention (CDC). Fertility clinics submit data to the CDC through the National ART Surveillance System (NASS) reporting system or an approved alternative compliant with federal reporting requirements. The CDC conducts data validation through yearly audits and site visits. The CDC has published Assisted Reproductive Technology Fertility Clinic Success Rates Reports detailing activity levels at an individual clinic level annually since 1997.

The Society for Assisted Reproductive Technology (SART), an organization of ART providers affiliated with the American Society for Reproductive Medicine (ASRM), has been collecting data and publishing annual reports of pregnancy success rates for fertility clinics in the United States and Canada since 1989. In 2017, of all the ART clinics reporting data to CDC, 82% were SART members.

Population comparison data was obtained from the 1999 to 2018 U.S. Natality files (Birth Cohort dataset) compiled annually by the CDC's National Center for Health Statistics (NCHS). The NCHS provides information on 99% of all registered births each year in the United States.

Definitions

We defined ART procedures as per the CDC, as all treatments or procedures that include the handling of human eggs or embryos to help a woman become pregnant. We defined a cycle of IVF as commencement of ovarian stimulation, or monitoring, with the intent of having an oocyte retrieval. This definition has been used by SART since 2014 and the CDC since 2017. This definition incorporates ovarian stimulation cycles which are cancelled, pre-implantation genetic testing is undertaken, or all embryos are frozen. For SART data before 2014 and CDC data from 1999 to 2016 a cycle was defined as "Fresh Embryos from Nondonor Eggs" (Table S1). Due to the different cycle definition used by the CDC for 2014 to 2016 (Table S2), an age-stratified multiplication value was derived using the aligned 2017 and 2018 SART and CDC records (Table S3) and applied to the CDC data for 2014 to 2016. The results from data transformation using the multiplication factor are presented in Table S4.

We defined a live-birth as delivery of one or more infants with any signs of life. The cumulative live-birth rate was defined as the probability of a live-birth from an ovarian stimulation encompassing all subsequent fresh and frozen embryo transfers from that stimulation. The total number of infants born allowing for multiples was determined from the annual Natality files and CDC ART reports (Table S5 along with predicted values in Table S6).

Age is the most important predictor of live birth following IVF treatment. We therefore stratified our analyses by age, using age categories consistent with the CDC and SART: less than 35 years, 35-37 years, 38-40 years, 41-42 years, more than 42 years.

Quantitative modelling on cycle activity

A quantitative prediction model was built using CDC data from 1999 to 2008, with four years onward prediction for 2009 to 2012. The predicted clinical activity was compared to the observed clinical activity after the 2008 financial recession and the percentage reduction in activity for each age category calculated (Table S7, S8).

A similar quantitative model was built to predict age-stratified cycle starts for 2020 to 2023, using baseline data from 2014 to 2018. We then applied the same percentage reduction in activity observed after 2008 (Table S9) to the period 2020 to 2023, for each age category (Table S10). This assumes that the impact of COVID -19 on cycle activity equates to a reduction like that observed after the 2008 financial recession. As sensitivity analyses, we modelled a less severe economic decline for the impact of COVID-19, by reducing the percentage reduction in activity by a factor of 0.5, and a more severe decline by increasing it by a factor of 0.5.

Impact of reduction in activity on live births

For the period 2009 to 2012 we multiplied the predicted cycle activity by the age-stratified cumulative live-birth rates as reported by the CDC in each of the respective annual ART Success Rates Reports. This predicted number of live-births for 2009 to 2012 was then compared to the observed live-births in the CDC ART annual reports.

For the period 2020 to 2023 we multiplied the different levels of predicted cycle activity (no recession, recession equivalent to 2008, less and more severe recession) by the age-stratified cumulative live birth rates reported in the most recent annual CDC 2018 report. This details the cumulative live-birth rates from 135,673 stimulation cycles undertaken by the 448 clinics in the USA that were commenced between January 1, 2017 and December 31, 2017, with inclusion of all embryo transfers that occurred within 12 months, and live-birth follow-up to October 2018 (CDC . 2019).

In addition to our main analyses (modelling the predicted impact of the economic recession due to COVID-19), we modelled the predicted impact of the two months closure of ART clinics. We previously showed that a shutdown of IVF treatment centers would result in a reduction in live-birth rate, and this reduction would differ with age (Smith *et al.* 2020). In the current study, we calculated the reduction caused by a two-month shutdown and applied this to the live-birth rate for each age strata in 2020 only, assuming that a shutdown would only occur in 2020.

Statistical analysis

The R 4.0.0 software environment was used for data analysis. “Forecast” package was used to perform auto regressive integrated moving average (ARIMA) prediction (Hyndman *et al.,* 2020). The presented total values reflect the sum of the predicted values including their decimalization.

Results

Figure 1 demonstrates the increase in IVF treatment provision over the last two decades, the increasing number of ART infants and their increasing contribution to all US births. The financial recession of 2008 was associated with the beginning of a decline in all US births, which has continued to present day and is predicted to continue (Figure 1, Table S6). In contrast, for ART there was evidence of a four-year plateau before recommencing an increase (Figure 1). During this plateau an estimated 53,026 (95% CI, 49,581 to 56,471) fewer IVF cycles were undertaken, increasing from 5,625 (95% CI, 5,462 to 5,788) fewer cycles in 2009 to 21,321 (95% CI, 19,589 to 23,053) by 2012, assuming similar underlying rates of growth prior to 2008 would have continued (Table S7).

There was strong evidence of an age-specific reduction over the ensuing four years; women aged less than 35 years undertook 5.16% (95% CI, 1.07 to 8.93) fewer IVF cycles in 2009 with a further reduction to 15.8% (95% CI, -1.01 to 27.82) fewer cycles in 2012, as compared to women aged more than 40 years where the reduction was 2.85% (95% CI, -0.87 to 6.31) in 2009 and 6.49% (95% CI -8.99% to 18.13%) in 2012 (Figure 2, Table S7). This estimated reduction in cycle activity between 2009 and 2012 equates to 16,872 (95% CI, 16,713 to 17,031) predicted fewer live births, with these predominantly being derived from younger women due to their higher success rates (Table S9).

Given the underlying growth of IVF treatment cycles we estimate that 139,760 (95% CI, 130,486 to 149,034) IVF treatment cycles would have been initiated in 2020, increasing to 151,690 (95% CI, 123,321 to 180,059) in 2023 (Table 1). Estimation of the effect of COVID-19 economic recession on IVF activity would predict that 67,386 (95% CI, 61,686 to

73,086) fewer IVF cycles will occur over this time frame, mostly from women younger than 35 years (Figure 3, Table 1).

With the closure of the IVF units for 2 months, the minor increase in maternal age will be associated with a small reduction (-0.7% (95% CI, -1.0 to -0.3%)) on the overall cumulative live-birth rates for treatments initiated over the whole population in 2020 (Table S10 and S11). This delay combined with the reduction in clinical activity due to COVID-19, is predicted to result in 3,414 (95% CI, 3,193 to 3,636) fewer live-births in 2020 (Table 2). With the overall (combining the impact of the economic recession and clinic closures) estimated reduction in IVF activity for 2020 to 2023, we predict 25,143 (95% CI, 22,408 to 27,877) fewer live births (Table 2). Sensitivity analyses estimating the impact of less and more severe economic recession following COVID-19 on IVF cycles and live births are shown in Tables S12 to S15.

Discussion

We demonstrate that the enduring growth of US fertility treatments temporarily halted after the 2008 financial crisis until 2012 and then resumed. Despite widespread economic adversity at this time, women over 40 years largely continued to pursue treatment as compared to younger women. With economic indicators suggesting an equivalent or even greater recession anticipated secondary to COVID-19, we estimate that the pandemic will result in 67,386 fewer IVF cycles being undertaken and 25,143 fewer live-births in the US over the next four years, equating to 12.7% fewer women having a baby from IVF, with the greatest reduction observed in women less than 40 years old. This reduction will be primarily driven by the anticipated economic recession, with clinic closures making only a small contribution. We acknowledge that these predicted decreases in IVF conceived live-births following the 2008 recession contribute <2% of the reduction in all live-births in the US at that time, and despite recent growth ART still constitutes <3% of US births. Thus, reductions in fertility treatments following the current COVID-19 related recession are not anticipated to have a major impact on population levels in the US or any other country. Nonetheless the now accepted right of couples to control their fertility, including through access to treatments, is likely to be importantly impacted.

For assisted conception which is predominantly self-funded by patients or insurers, the loss of employment or financial security may have been responsible for the plateau in the aftermath of the 2008 financial recession. That women older than 40 aged exhibited the lowest percentage reduction in clinical activity potentially reflects their greater appreciation of the age-related decline in both spontaneous fecundity (Menken *et al.* 1986) and IVF success rates (Lawlor and Nelson 2012, Smith *et al.* 2015). Furthermore, a decision to not pursue fertility treatments would have the greatest impact on older women as assisted reproductive technology births equate to 11.8% of all births in women over the age of 40, as compared to 4.4% in women aged 35-39 years, and 0.9% in women under 35 years (Levine *et al.* 2017). Older women are also likely to be more financially secure than younger women.

The disruptive economic repercussions of COVID-19 continue to be elucidated with the use of high-frequency indicators of economic fluctuations, such as unemployment insurance claims, which breached 30 million in the first six weeks of the pandemic, implying a dramatic reduction in future employment and labour force participation (Baldwin and Weder di Mauro, U.S. Bureau of Labour Statistics 2020). At present the longer-term projections exceed the 2008 crisis, and if the recovery is muted it could take more than 5 years for the most affected sectors to return to 2019-level contributions to GDP. This backdrop of financial uncertainty is likely to translate into a relative reduction in fertility related treatment. We anticipate that like 2008, the greatest reduction in clinical activity will be in younger women, who will perceive that they may be able to wait and conceive naturally and / or are unable to afford treatment. Reductions in IVF in this age-group will however have the largest overall impact on birth rates due to the volume of activity and relative high success rates. Given the relatively small contribution of ART births to all US births the greatest threat to the population is from younger women deciding to postpone natural conception or decide against further children due to economic uncertainty (Figure 1 or Table S5). That this would occur at a time when US fertility rates are already substantially below replacement levels will have further profound impacts on population age structures (Vollset *et al.* 2020).

Contracting economies may also affect health by impeding adherence to preventive measures or adoption of unhealthy lifestyle characteristics. Economic downturns have been associated with increases rates of obesity (Ludwig and Pollack 2009), reduce attempts at smoking cessation (Gallus *et al.* 2016), increased incidence of sexually transmitted infections (Pérez-Morente *et al.* 2019) all of which would further impede spontaneous and assisted conception. Perinatal outcomes may also be compromised as economic adversity has been associated with an increased risk of miscarriage (Bruckner *et al.* 2016) and stillbirths (Vlachadis and Kornarou 2013).

Our results show that economic recession erodes the accepted rights of couples to have their desired family. Amid an absence of public funding, and patchwork of state mandates for insurance provision, an economic recession will exacerbate unequal access to health care, especially for minorities. Lack of an infertility insurance mandate has previously been associated with an increased risk of triplets and high order multiples, preterm birth and low birth weight (Boulet *et al.* 2015), as patients may seek more affordable treatments and take higher risks to address involuntary childlessness. In countries where health-care provision is equally accessible irrespective of employment or insurance status, access to fertility treatment will be less problematic and declining birth rates may be less exacerbated by COVID-19.

Although we have used the 2008 financial recession to estimate the effect of an economic recession, the COVID-19 related recession is still estimated to be substantially greater despite significant appeasement measures (McKibbin and Fernando 2020, Nicola *et al.* 2020). When combined with societal changes, our sensitivity analyses of less or more severe effects would potentially cover the range of plausible scenarios and impact on IVF cycles and birth rates. In support of our predicted decline, the UK reported 4% fewer 12 week scans were undertaken by the NHS in 2020 as compared to 2019 (Kekatos 2020). In the US five states have reported 80,000 fewer births in 2020 (others are still awaited), with California reporting a 13.7% year on year reduction (Kekatos 2020, State Health Departments 2020). The

Brookings Institute have recently (17 December 2020) estimated that 206,000 fewer births will occur in 2021. Wilde and colleagues have shown that search terms which predict societal behaviour and fertility have also decreased (Wilde *et al.* 2020). Collectively this data would all support our predictions that there will be a detrimental impact on IVF related and natural births.

We have modelled four different scenarios (no impact, same as 2008, 50% less than 2008 and 50% more than 2008), on how the COVID-19 may influence the fertility rate and IVF treatments in the USA. We acknowledge that these models are primarily based on fertility rates over last two decades and the 2008 financial crisis, but in doing so our models account for underlying trends including technological developments, societal changes and concerns while also allowing for the black swan event of the COVID-19 pandemic and the associated economic, public health and societal impact which may be less or more severe than observed after 2008 event. Our different sensitivity analyses would allow for this variation irrespective of the cause, which may include changes in provision of healthcare with new government, altered business models or societal concerns regarding having children during or in the immediate aftermath of the pandemic.

Quantitative and qualitative research with couples could add important insights into the validity of our different assumptions and hence narrow the range of possibilities we present. We hope that this initial study will stimulate funding for such further research on the impact of the pandemic on reproduction and ART.

We note several additional limitations of our study. We evaluated population health outcomes and economic trends and did not account for variations at regional or subnational levels, which may mask variations particularly as the percentage of children born via assisted conception varies from high levels in some states such as Massachusetts (4.8%) to low in Puerto Rico (0.2%) (Thompson 2016). For reasons of data availability and definitions we utilised total treatment cycles to develop our growth estimates, thereby allowing for variations in clinical practice and contextualisation of the 2008 financial crisis over two decades. We are unaware of any other reasons for the observed plateau, with the resumption of growth in 2012 aligning with other improvements in macroeconomic indicators. We have assumed an equivalent economic challenge due to COVID-19 as observed in 2008, however, we have performed sensitivity analyses for both a less or more severe impact and the true estimate on cycles and live births is likely to lie between these two extremes. Our prediction methods assume that past activity is a reliable indicator of future activity; we discuss these assumptions and show our predictions are not sensitive to them in Supplementary Material. Lastly, our estimates of live-birth reflect current reported success rates for all treatments performed within 12 months of the initiated stimulation cycle as per CDC and SART, we acknowledge that additional frozen embryo transfers may occur beyond this time-frame resulting in some additional live-births that are unaccounted for. It is also possible that improvements in treatment, which we cannot predict, will cause a relative increase in future live-birth rates for some age groups.

We demonstrate the detrimental impact of the 2008 economic crisis on the uptake of fertility treatment, and that older women largely persisted in seeking assistance. We estimate that the COVID-19 related economic recession will be associated with about 25,143 fewer live births over the next four years, with the greatest reduction observed in women who are 35-40 year olds where ART related births constitute 4.4% of all US births.

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Competing interests

No funding bodies had any role in study design, data collection and analysis, decision to publish, or preparation of the manuscript. SMN has participated in Advisory Boards and received speakers or consultancy fees from Access Fertility, Beckman Coulter, Ferring, Finox, Merck, MSD, Roche Diagnostics and The Fertility Partnership. DAL has received grant funding for other studies, not related to this one, from government, charity and industry funders, including Roche Diagnostics and Medtronic.

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Figure legends

Figure 1: ART cycles, ART infants and all US births from 1999 to 2018 with 5 years prediction (blue line) along with 95% confidence intervals (shade blue). (A) The observed (red points) total number of ART cycles undertaken in the US over 20 years with 5 years predication. (B) The total number of ART infants born per annum with five years prediction. (C) The proportion of ART infants over studied years as a percentage of (D) the total number of infants born within the US for 1999 to 2018, with onward prediction for 2019 to 2023.
Actual values for number of all and ART infants for 1999 to 2018 are provided in Supplemental Table S2 with predictions provided in Table S6.

Figure 2: Observed and projected IVF cycle activity around 2008 financial crisis. The observed age-stratified number of cycles between 1999 and 2008 (red solid points), was used to predict number of cycles for 2009 to 2013 (solid blue line with 95% confidence intervals), as compared to the observed number of cycles (black open circles). (A) Nr. of cycles over years for a women with age <35. (B) Nr. of cycles over years for a women with age 35-37. (C) Nr. of cycles over years for a women with age 38-40. (D) Nr. of cycles over years for a women with age 41-42.
Age >42 was not included due to the lack of reporting the data in some of the investigated years.

Figure 3: Observed and projected IVF cycle activity in response to COVID-19 financial crisis.

The observed age-stratified number (A – below 35, B – 35-37, C – 38-40, D – 41-42, E – above 42) of cycles between 2013 and 2018 (red solid points), was used to predict number of cycles for 2019 to 2023 (solid blue line with 95% confidence intervals). The estimated shifts reflect the age strata specific percentage decline observed after the 2008 crisis (black line), with a 50% less severe impact (yellow solid line) or 50% more severe impact (orange line).

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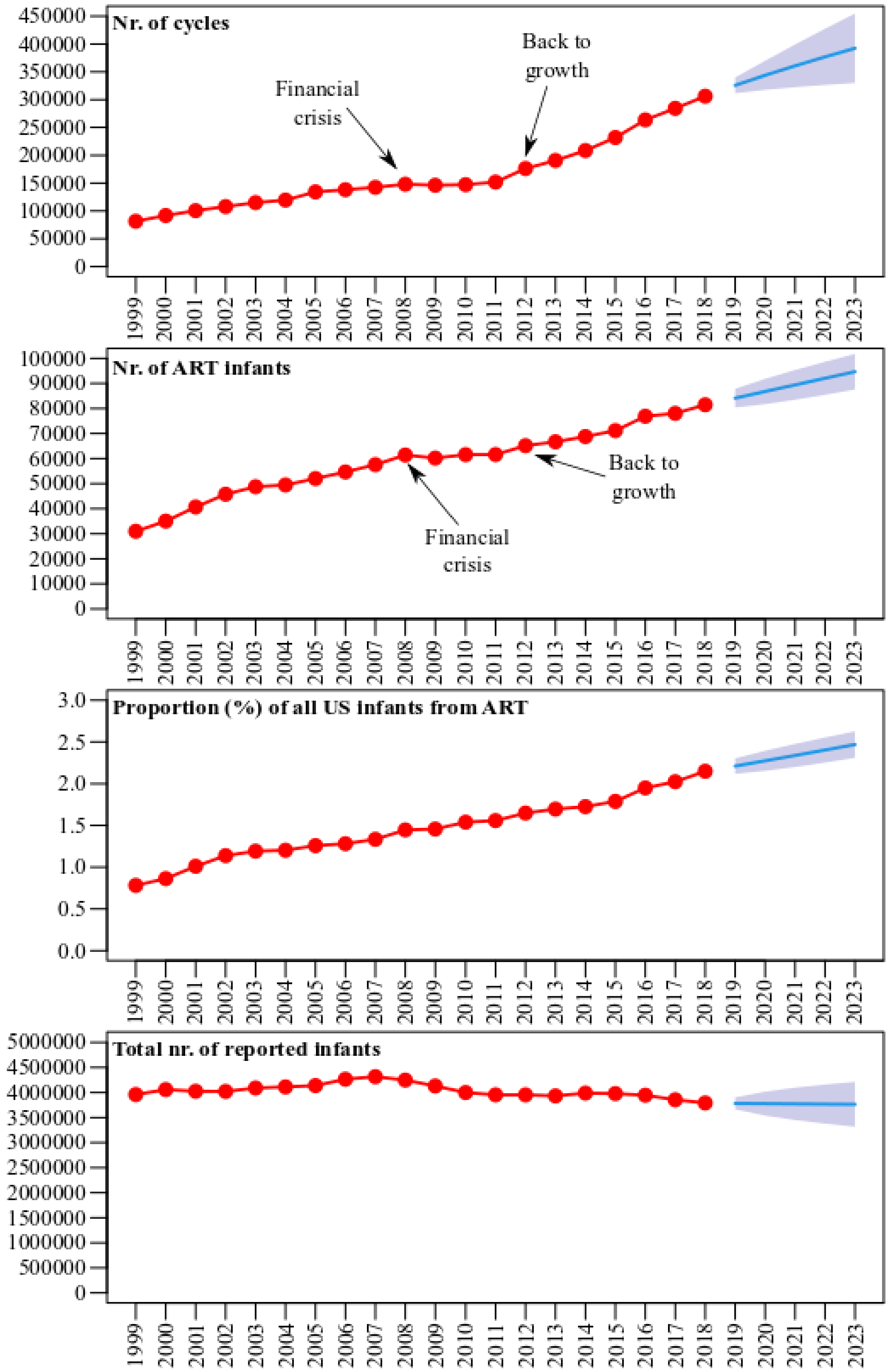
Figure 1


Nr. of cycles
Financial crisis
Back to growth
Nr. of ART infants
Back to growth
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Proportion (%) of all US infants from ART
Total nr. of reported infants

Figure 2

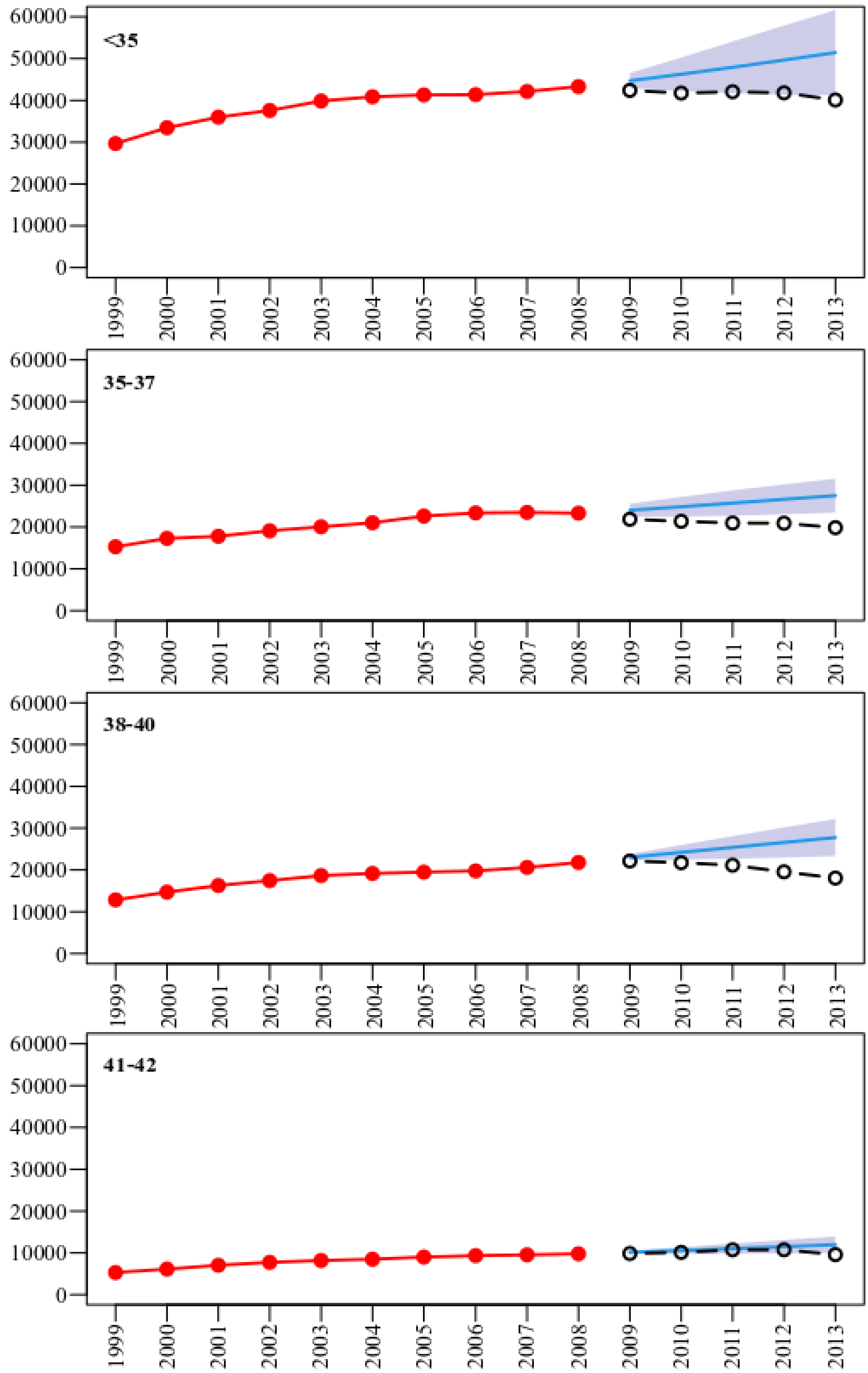

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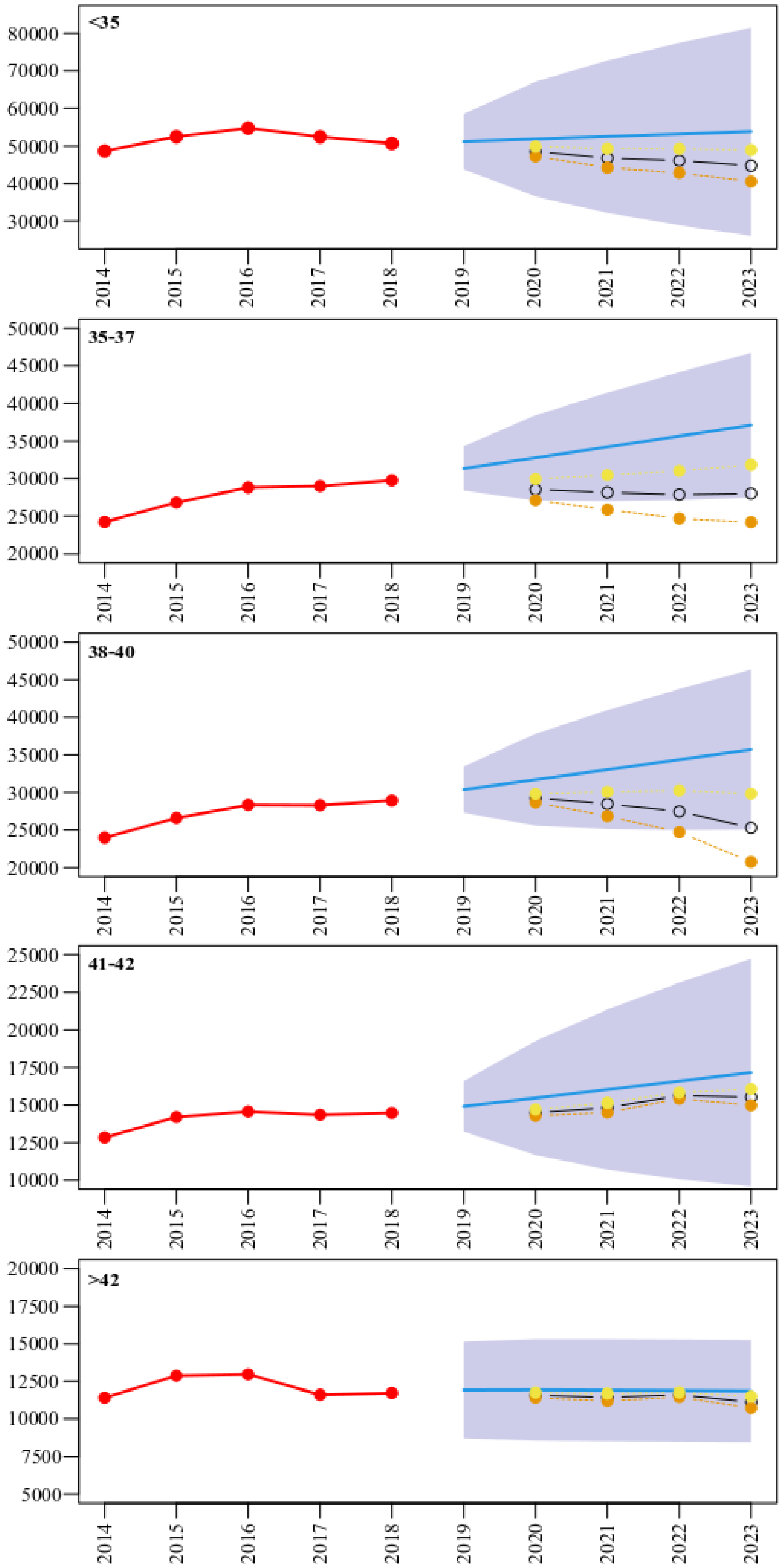
Figure 3



<35
80000
70000
60000
50000
40000
30000
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
35-37
50000
45000
40000
35000
30000
25000
20000
38-40
41-42
25000
22500
20000
17500
15000
12500
10000
>42
7500
5000

Table 1 Estimated changes in number of IVF fresh nondonor cycles over the period 2020-2023 with implication of economic crisis triggered by COVID-19 by age of patients.

Age group (years)	**Without COVID-19 impact Nr. of cycles (95% CI)***		**Percentage reduction in cycles**	**With COVID-19 impact Nr. of cycles (95% CI)***		I
	Year: 2020					
< 35	51,170	(43,798~58,542)	-5.16%	48,530	(41,538~55,522)	-2,64
35-37	31,358	(28,389~34,327)	-9.00%	28,536	(25,834~31,238)	-282
38-40	30,385	(27,296~33,474)	-3.76%	29,243	(26,270~32,216)	-114
41-42	14,924	(13,234~16,615)	-2.85%	14,499	(12,857~16,141)	-42
>42	11,923	(8,691~15,155)	-2.85%	11,583	(8,443~14,723)	-34
Total	139,760	(130,486~149,034)	-5.27%	132,391	(123,583~141,199)	-7,36
	Year: 2021					
< 35	51,835	(36,545~67,126)	-9.75%	46,781	(32,981~60,581)	-5,05
35-37	32,771	(27,096~38,446)	-14.06%	28,163	(23,286~33,040)	-4,60
38-40	31,704	(25,583~37,825)	-10.20%	28,470	(22,973~33,967)	-3,23
41-42	15,469	(11,670~19,268)	-4.11%	14,833	(11,190~18,476)	-63
>42	11,935	(8,553~15,318)	-4.11%	11,444	(8,201~14,687)	-49
Total	143,714	(125,566~161,862)	-9.76%	129,691	(98,633~160,752)	-14,02
	Year: 2022					
< 35	52,499	(32,207~72,792)	-12.21%	46,089	(28,274~63,904)	-641
35-37	34,222	(27,014~41,431)	-18.56%	27,870	(21,999~33,741)	-635
38-40	33,041	(25,126~40,956)	-16.81%	27,487	(20,902~34,072)	-555
41-42	16,034	(10,707~21,362)	-2.52%	15,630	(10,437~20,823)	-40
>42	11,913	(8,507~15,318)	-2.52%	11,613	(8,293~14,933)	-30
Total	147,709	(123,910~171,508)	12.88%	128,689	(107,876~149,502)	-19,02
	Year: 2023					
< 35	53,163	(28,878~77,448)	-15.80%	44,763	(24,315~65,211)	-8,40
35-37	35,665	(27,153~44,177)	-21.43%	28,022	(21,334~34,710)	-7,64
38-40	34,376	(24,987~43,765)	-26.42%	25,294	(18,386~32,202)	-9,08
41-42	16,603	(10,059~23,147)	-6.49%	15,525	(9,406~21,644)	-1,07
>42	11,883	(8,474~15,293)	-6.49%	11,112	(7,924~14,300)	-77
Total	151,690	(123,321~180,059)	-17.78%	124,716	(101,090~148,342)	-26,97

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling

Table 2 Estimated changes in number of IVF live births over the period 2020-2023 with implication of economic crisis triggered by COVID-19 by age of patients.

Age group (years)	Without COVID-19 impact Live births (95% CI)*		With COVID-19 impact Live births (95% CI)*		Difference (95% CI)*	
	Year: 2020					
< 35	26,404	(22,593~30,214)	24,884	(21,293~28,475)	-1,520	(-1,739~-1,301)
35-37	11,759	(10,632~12,886)	10,487	(9,482~11,493)	-1,272	(-1,393~-1,150)
38-40	7,140	(6,399~7,882)	6,705	(6,009~7,401)	-435	(-480~-391)
41-42	1,761	(1,547~1,975)	1,611	(1,414~1,807)	-150	(-169~-132)
>42	405	(289~522)	369	(262~475)	-37	(-47~-26)
Total	47,470	(43,421~51,519)	44,056	(40,255~47,856)	-3,414	(-3,663~-3,165)
	Year: 2021					
< 35	26,747	(18,854~34,640)	24,139	(17,016~31,262)	-2,608	(-3,377~-1,838)
35-37	12,289	(10,153~14,425)	10,561	(8,726~12,397)	-1,728	(-2,028~-1,428)
38-40	7,450	(6,003~8,897)	6,690	(5,391~7,990)	-760	(-908~-612)
41-42	1,825	(1,370~2,281)	1,750	(1,313~2,187)	-75	(-94~-56)
>42	406	(284~527)	389	(273~506)	-17	(-22~-12)
Total	48,718	(40,400~57,035)	43,530	(36,046~51,014)	-5,188	(-6,021~-4,354)
	Year: 2022					
< 35	27,089	(16,616~37,563)	23,782	(14,587~32,976)	-3,308	(-4,586~-2,029)
35-37	12,833	(10,123~15,543)	10,451	(8,244~12,658)	-2,382	(-2,885~-1,879)
38-40	7,765	(5,897~9,632)	6,459	(4,906~8,013)	-1,305	(-1,619~-991)
41-42	1,892	(1,258~2,526)	1,844	(1,226~2,463)	-48	(-64~-32)
>42	405	(283~527)	395	(276~514)	-10	(-13~-7)
Total	49,984	(38,987~60,982)	42,932	(33,329~52,535)	-7,053	(-8,447~-5,659)
	Year: 2023					
< 35	27,432	(14,899~39,965)	23,098	(12,545~33,651)	-4,334	(-6,315~-2,354)
35-37	13,374	(10,176~16,573)	10,508	(7,995~13,021)	-2,866	(-3,551~-2,181)
38-40	8,078	(5,865~10,291)	5,944	(4,316~7,572)	-2,134	(-2,719~-1,550)
41-42	1,959	(1,182~2,736)	1,832	(1,105~2,559)	-127	(-178~-77)
>42	404	(282~526)	378	(263~492)	-26	(-34~-18)
Total	51,248	(38,102~64,394)	41,760	(30,766~52,754)	-9,488	(-11,640~-7,336)

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling.

Supplementary Appendix

Content

1. Data

In this study we have employed two data sets: CDC and SART. From CDC data set summary of assisted reproductive technology (ART) success rates report in Excel format were copied from: https://www.cdc.gov/art/artdata/index.html. Each of the report's cycles started and was carried out in different increasing number of clinics each year, and the outcomes of these cycles, during each calendar year were deposited in Excel spreadsheets. At this point, from each of downloaded spreadsheets since 1999 we have extracted the number of cycles reported for fresh nondonor eggs strata by age of patients. For this purpose, as can be observed in **Table S1** we have used abbreviations as defined in description spreadsheet and collected the number of cycles strata by patient's age along with total number of cycles per each calendar year since 1999 till 2018. The total number of cycles was used in order to highlight the change in the number of cycles due to finical crisis and the amount of time to come back to steady growth.

The data from 1999-2013 were used with the purpose of simulation of potential growth of the number of cycles as observed over five years doubt that financial crisis in 2008 did not happen. The ARIMA model estimate *circa* five years increase of the number of cycles either in fresh nondonor eggs or total number of cycles. This numbers then are used to estimate percentage decrease/slow down in the fresh nondonor or total number of cycles.

Table S1. ART success rates report since 1999 for fresh embryo nondonor eggs cycles by age of patients.

Year	Abbreviation	Description	Nr fresh nondonor cycles	Total nr ART treatments*
1999	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	29,682	81,483
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	15,291	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	12,848	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	5,302	
2000	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	33,453	91,779
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	17,284	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	14,701	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	6,118	
2001	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	35,984	100,552
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	17,791	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	16,283	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	7,044	
2002	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	37,591	107,927
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	19,110	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	17,454	

	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	7,733	
2003	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	39,852	114,963
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	20,056	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	18,660	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	8,185	
2004	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	40,853	119,551
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	21,019	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	19,174	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	8,487	
2005	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	41,301	134,260
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	22,622	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	19,485	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	8,997	
2006	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	41,369	138,198
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	23,376	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	19,775	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,346	
2007	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	42,127	142,435
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	23,504	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	20,612	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,535	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,814	
2008	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	43,296	148,055
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	23,326	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	21,793	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,783	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,907	
2009	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	42,384	146,244
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	21,860	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	22,144	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,845	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,857	
2010	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	41,741	147,260
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	21,366	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	21,739	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	10,120	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,501	
2011	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	42,059	151,923
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	20,963	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	21,128	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	10,733	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,744	
	FshNDCycle6	(Fresh Nondonor Eggs) Number of cycles >44	1,586	
2012	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	41,798	176,247
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	20,920	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	19,556	

	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	10,740	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	5,050	
	FshNDCycle6	(Fresh Nondonor Eggs) Number of cycles >44	1,601	
2013	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	40,083	190,773
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	19,853	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	18,061	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,588	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,823	
	FshNDCycle6	(Fresh Nondonor Eggs) Number of cycles >44	1,379	
2014	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	39,573	208,604
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	19,376	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	17,617	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	9,114	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	5,131	
	FshNDCycle6	(Fresh Nondonor Eggs) Number of cycles >44	2,051	
2015	FshNDCycle1	(Fresh Nondonor Eggs) Number of cycles <35	39,302	231,936
	FshNDCycle2	(Fresh Nondonor Eggs) Number of cycles 35-37	19,023	
	FshNDCycle3	(Fresh Nondonor Eggs) Number of cycles 38-40	17,191	
	FshNDCycle4	(Fresh Nondonor Eggs) Number of cycles 41-42	8,872	
	FshNDCycle5	(Fresh Nondonor Eggs) Number of cycles 43-44	4,940	
	FshNDCycle6	(Fresh Nondonor Eggs) Number of cycles >44	1,762	
2016	FshNDCycle1	Frsh emb Frsh nondnr egg <35	36,625	263,577
	FshNDCycle2	Frsh emb Frsh nondnr egg 35-37	18,278	
	FshNDCycle3	Frsh emb Frsh nondnr egg 38-40	16,109	
	FshNDCycle4	Frsh emb Frsh nondnr egg 41-42	8,264	
	FshNDCycle5	Frsh emb Frsh nondnr egg >42	6,961	
2017	ND_NumIntentRet1	Nondonor eggs, All patients <35	52,428	284,385
	ND_NumIntentRet2	Nondonor eggs, All patients 35-37	28,996	
	ND_NumIntentRet3	Nondonor eggs, All patients 38-40	28,287	
	ND_NumIntentRet4	Nondonor eggs, All patients 41-42	14,358	
	ND_NumIntentRet5	Nondonor eggs, All patients ≥43	11,604	
2018	ND_NumIntentRet1	Nondonor eggs, All patients <35	50,651	306,197
	ND_NumIntentRet2	Nondonor eggs, All patients 35-37	29,766	
	ND_NumIntentRet3	Nondonor eggs, All patients 38-40	28,917	
	ND_NumIntentRet4	Nondonor eggs, All patients 41-42	14,483	
	ND_NumIntentRet5	Nondonor eggs, All patients ≥43	11,725	

* Total nr. of all ART treatments performed in a year.

Due to a different reporting style of CDC data between 2014-2016 we have used SART data (**Table S2**) to estimate multiplication factor (**Table S3**) and consequently convert it to CDC format (**Table S4**) further used for forecasting of COVID-19. Here, as discussed in the manuscript a multiplication factor was used and the values of conversion are presented.

Table S2. Number of cycles between 2014-2018 for a patient's own eggs- live births per intended egg retrieval (all embryo transfers) extracted from https://www.sartcorsonline.com/Csr/Public.

Year of record	Age group (years) < 35	35 - 37	38 - 40	41 - 42	> 42
2014	41,063	21,407	20,732	11,106	8,611
2015	44,268	23,689	22,999	12,281	9,714
2016	46,189	25,448	24,495	12,601	9,784
Values used to calculate average multiplication factor					
2017	44,191	25,876	24,503	12,258	8,675
2018	42,820	26,027	24,957	12,686	8,931

Table S3. Multiplication factor per each age strata.

Age of woman	< 35	35 - 37	38 - 40	41 - 42	> 42
Average multiplication factor	1.18	1.13	1.16	1.16	1.33

Table S4. Outcomes of conversion SART to CDC.

Year of record	Age group (years) < 35	35 - 37	38 - 40	41 - 42	> 42
2018	50,651	29,766	28,917	14,483	11,725
2017	52,428	28,996	28,287	14,358	11,604
2016	54,747	28,812	28,335	14,575	12,968
2015	52,470	26,821	26,605	14,205	12,875
2014	48,671	24,237	23,982	12,846	11,413

Table S5. Total number of infants born, number of ART infants and the proportion of infants born from ART within the US for 1999 to 2018.

Year	Nr. of infants born*	Nr. of ART infants†	Percentage of infants born from ART
1999	3,959,417	30,967	0.78%
2000	4,058,814	35,025	0.86%
2001	4,025,933	40,687	1.01%
2002	4,021,726	45,751	1.14%
2003	4,089,950	48,756	1.19%
2004	4,112,052	49,458	1.20%
2005	4,138,349	52,041	1.26%
2006	4,265,555	54,656	1.28%
2007	4,316,233	57,569	1.33%
2008	4,247,694	61,426	1.45%
2009	4,130,665	60,190	1.46%
2010	3,999,386	61,564	1.54%
2011	3,953,590	61,610	1.56%
2012	3,952,841	65,151	1.65%
2013	3,932,181	66,691	1.70%
2014	3,988,076	68,782	1.72%

2015	3,978,497	71,152	1.79%
2016	3,945,875	76,892	1.95%
2017	3,855,500	78,052	2.02%
2018	3,791,712	81,478	2.15%

*Data obtained from U.S. Natality files (Birth Cohort dataset) compiled annually by the Center for Disease Control and Prevention's National Center for Health Statistics (NCHS).
†ART infants obtained from the annual CDC ART Success Rates Reports

For prediction of the number of cycles that would have occurred if the underlying growth had continued, we used the R 4.0.0 software environment with the "Forecast" package to perform auto regressive integrated moving average (ARIMA) prediction. This method assumes that future activity can be predicted based on past trends and no other variables. It also assumes a constant variance in errors around predictions, and no sudden changes in activity. We have therefore used it to predict clinical activity in 2009 to 2012 and 2020 to 2023 in the absence of external changes due to the 2008 recession and COVID-19 pandemic respectively.

Table S6. Prediction of total number of infants born; number of ART infants and the proportion of infants born from ART within the US for 2019 to 2023.

Year	Predicted number	Lower 95% CI	Upper 95% CI
5-year prediction of number of infants to be born			
2019	3,782,792	3,662,758	3,902,826
2020	3,777,939	3,538,256	4,017,623
2021	3,773,558	3,449,843	4,097,273
2022	3,769,231	3,378,530	4,159,931
2023	3,764,910	3,317,069	4,212,751
5-year prediction of number of ART infants to be born			
2019	84,134	80,395	87,873
2020	86,782	81,720	91,844
2021	89,424	83,476	95,371
2022	92,059	85,460	98,659
2023	94,690	87,588	101,792
5-year prediction of proportion of infants born from ART (%)			
2019	2.21	2.12	2.3
2020	2.27	2.15	2.4
2021	2.34	2.20	2.48
2022	2.40	2.25	2.55
2023	2.47	2.31	2.63

A quantitative prediction model was built using CDC data from 1999 to 2008, with four years onward prediction for 2009 to 2012 (Table S7). A similar quantitative model was built to predict age-stratified cycle starts for 2020 to 2023, using baseline data from 2014 to 2018. As a sensitivity analyses we also modelled only using 5 years data from 2004 to 2008 to predict 2009 to 2012 (Table S8) activity levels as 5 years data (2014 to 2018) was used to predict 2020 to 2023.

Table S7. Reported number of cycles and predicted number of cycles for 2009 to 2012.

	Reported Nr. of cycles †	Percentage reduction in cycles	Predicted number of cycles Nr. of cycles (95% CI)*		Difference (95% CI)*	
	Year: 2009					
< 35	42,384	-5.16% (-8.93~-1.07)	44,692	(42,842-46,542)	-2,308	(-2,404~-2,212)
35-37	21,860	-9.00% (-14.51~-2.74)	24,023	(22,476-25,570)	-2,163	(-2,302~-2,024)
38-40	22,144	-3.76% (-6.98~-0.31)	23,009	(22,212-23,806)	-865	(-895~-835)
41-42	9,845	-2.85% (-6.31~0.87)	10,134	(9,760-10,508)	-289	(-300~-278)
Total	96,233	-5.52% (-7.84~-3.08)	101,858	(99,291-104,425)	-5,625	(-5,788~-5,462)
	Year: 2010					
< 35	41,741	-9.75% (-16.95~-1.16)	46,248	(42,232-50,263)	-4,507	(-4,898~-4,115)
35-37	21,366	-14.06% (-21.57~-4.96)	24,862	(22,482-27,242)	-3,496	(-3,831~-3,161)
38-40	21,739	-10.2% (-16.29~-3.16)	24,208	(22,448-25,969)	-2,469	(-2,649~-2,290)
41-42	10,120	-4.11% (-11.10~4.07)	10,554	(9,724-11,383)	-434	(-468~-399)
Total	94,966	-10.3% (-14.39~-5.80)	105,872	(100,815-110,929)	-10,906	(-11,441~-10,371)
	Year: 2011					
< 35	42,059	-12.21% (-22.26~0.81)	47,910	(41,721-54,099)	-5,851	(-6,607~-5,095)
35-37	20,963	-18.56% (-27.14~-7.68)	25,740	(22,707-28,772)	-4,777	(-5,339~-4,214)
38-40	21,128	-16.81% (-24.84~-6.86)	25,397	(22,685-28,109)	-4,269	(-4,725~-3,813)
41-42	10,733	-2.52% (-12.48~10.00)	11,010	(9,757-12,263)	-277	(-309~-245)
Total	94,883	-13.79% (-19.30~-7.47)	110,057	(102,545-117,569)	-15,174	(-16,189~-14,159)
	Year: 2012					
< 35	41,798	-15.8% (-27.82~1.01)	49,644	(41,381-57,907)	-7,846	(-9,152~-6,540)
35-37	20,920	-21.43% (-30.74~-9.24)	26,627	(23,050-30,204)	-5,707	(-6,474~-4,940)
38-40	19,556	-26.42% (-35.21~-14.87)	26,578	(22,971-30,185)	-7,022	(-7,975~-6,069)
41-42	10,740	-6.49% (-18.13~8.99)	11,486	(9,854-13,119)	-746	(-853~-640)
Total	93,014	-18.65% (-25.09~-10.99)	114,335	(104,499-124,171)	-21,321	(-23,053~-19,589)

† number of fresh embryo nondonor cycles
*Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling using data from 1999 to 2008 as baseline.

Table S8. Reported number of cycles and predicted number of cycles modelled only using 5 years of available data from 2004 to 2008 to assess data for 2009 to 2012 using 5 years of baseline data for prediction.

	Reported Nr. of cycles †	**Percentage reduction in cycles**	**Predicted number of cycles Nr. of cycles (95% CI)***		**Difference (95% CI)***	
	Year: 2009					
< 35	42,384	-3.81% (-6.52~-0.93)	44,062	(42,783~45,341)	-1,678	(-1,727~-1,629)
35-37	21,860	-5.75% (-11.8~1.19)	23,193	(21,602~24,785)	-1,333	(-1,425~-1,242)
38-40	22,144	-2.79% (-6.63~1.38)	22,779	(21,843~23,716)	-635	(-662~-609)
41-42	9,845	-2.67% (-5.76~0.63)	10,115	(9,783~10,447)	-270	(-279~-261)
Total	96,233	-3.91% (-6.04~-1.68)	100,149	(97,878~102,420)	-3,916	(-4,019~-3,813)
	Year: 2010					
< 35	41,741	-6.60% (-11.45~-1.19)	44,691	(42,244~47,138)	-2,950	(-3,112~-2,788)
35-37	21,366	-8.53% (-22.51~11.61)	23,358	(19,144~27,572)	-1,992	(-2,351~-1,633)
38-40	21,739	-7.74% (-15.52~1.62)	23,563	(21,392~25,734)	-1,824	(-1,992~-1,656)
41-42	10,120	-3.27% (-9.68~4.13)	10,462	(9,719~11,205)	-342	(-366~-318)
Total	94,966	-6.96% (-11.63~-1.78)	102,074	(96,688~107,460)	-7,108	(-7,533~-6,683)
	Year: 2011					
< 35	42,059	-7.25% (-13.21~-0.43)	45,349	(42,239~48,458)	-3,290	(-3,515~-3,064)
35-37	20,963	-11.61% (-31.42~24.30)	23,717	(16,865~30,568)	-2,754	(-3,549~-1,958)
38-40	21,128	-13.02% (-22.92~-0.19)	24,291	(21,169~27,412)	-3,163	(-3,569~-2,756)
41-42	10,733	-0.73% (-9.44~9.85)	10,812	(9,771~11,852)	-79	(-86~-71)
Total	94,883	-8.91% (-15.57~-1.12)	104,169	(95,957~112,381)	-9,286	(-10,189~-8,383)
	Year: 2012					
< 35	41,798	-9.13% (-15.85~-1.25)	46,000	(42,328~49,672)	-4,202	(-4,537~-3,867)
35-37	20,920	-13.56% (-37.67~40.97)	24,201	(14,840~33,563)	-3,281	(-4,551~-2,012)
38-40	19,556	-21.79% (-32.32~-7.37)	25,003	(21,112~28,893)	-5,447	(-6,294~-4,599)
41-42	10,740	-3.78% (-13.66~8.65)	11,162	(9,885~12,439)	-422	(-470~-374)
Total	93,014	-12.55% (-20.65~-2.61)	106,366	(95,508~117,224)	-13,352	(-14,861~-11,843)

† number of fresh embryo nondonor cycles.

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling using data from 1999 to 2008 as baseline.

Table S9. Predicted number of live-births after 2008 financial recession and observed number.

	Reported Nr. of cycles †	Percentage of cycles resulting in live births (95% CI)	Predicted number of cycles*	Number of live births based on reported nr. of cycles	Estimated number of liv births based on predicted n cycles (95% CI)*
	Year: 2009				
< 35	42,384	41.2% (40.73%, 41.67%)	44,692	17,462	18,413 (18,203-18,623)
35-37	21,860	31.6% (30.99%, 32.22%)	24,023	6,908	7,591 (7,443-7,739)
38-40	22,144	22.3% (21.76%, 22.85%)	23,009	4,938	5,131 (5,006-5,256)
41-42	9,845	12.4% (11.76%, 13.07%)	10,134	1,221	1,257 (1,191-1,323)
Total	96,233		101,858	30,529	32,392 (32,099-32,685)
	Year: 2010				
< 35	41,741	41.5% (41.03%, 41.97%)	46,248	17,323	19,193 (18,975-19,411)
35-37	21,366	31.9% (31.28%, 32.53%)	24,862	6,816	7,931 (7,776-8,086)
38-40	21,739	22.1% (21.55%, 22.66%)	24,208	4,804	5,350 (5,216-5,484)
41-42	10,120	12.4% (11.77%, 13.06%)	10,554	1,255	1,309 (1,241-1,377)
Total	94,966		105,872	30,198	33,783 (33,476-34,090)
	Year: 2011				
< 35	42,059	40% (39.53%, 40.47%)	47,910	16,824	19,164 (18,939-19,389)
35-37	20,963	31.9% (31.27%, 32.53%)	25,740	6,687	8,211 (8,049-8,373)
38-40	21,128	21.5% (20.95%, 22.06%)	25,397	4,543	5,460 (5,319-5,601)
41-42	10,733	12.1% (11.5%, 12.73%)	11,010	1,299	1,332 (1,264-1,400)
Total	94,883		110,057	29,353	34,167 (33,849-34,485)
	Year: 2012				
< 35	41,798	40.5% (40.03%, 40.97%)	49,644	16,928	20,106 (19,873-20,339)
35-37	20,920	31.3% (30.68%, 31.93%)	26,627	6,548	8,334 (8,167-8,501)
38-40	19,556	22.2% (21.62%, 22.79%)	26,578	4,341	5,900 (5,744-6,056)
41-42	10,740	11.7% (11.11%, 12.32%)	11,486	1,257	1,344 (1,275-1,413)
Total	93,014		114,335	29,074	35,684 (35,350-36,018)

† number of fresh embryo nondonor cycles.

*Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling using data from 1999 to 2008 as baseline.

Table S10. Estimated changes in IVF within-cycle live-birth rate over the period 2020-2023 with implication of economic crisis triggered by COVID-19 by year.

Year	Without Covid-19 impact Within-cycle live-birth rate (95% CI)*		With Covid-19 impact Within-cycle live-birth rate (95% CI)*		Difference (95% CI)*	
2020	34.0%	(33.7%~34.2%)	33.3%	(33.0%~33.5%)	-0.7%	(-1.0%~-0.3%)
2021	33.9%	(33.7%~34.1%)	33.6%	(33.3%~33.5%)	-0.3%	(-0.7%~0.0%)
2022	33.8%	(33.6%~34.1%)	33.4%	(33.1%~33.6%)	-0.5%	(-0.8%~-0.1%)
2023	33.8%	(33.5%~34.0%)	33.5%	(33.2%~33.7%)	-0.3%	(-0.7%~0.1%)

* Rounded (due to decimalization) prediction outcomes based on ARIMA modelling.

Table S11. Estimated IVF within-cycle live-birth rate over the period 2020-2023 with implication of 2 months treatment shutdown triggered by COVID-19 by age of patients.

Age group (years)	Within-cycle live-birth rate (95% CI)*			
	Year: 2020		Years: 2021-2023	
< 35	51.3%	(50.8%~51.7%)	51.6%	(51.2%~52.0%)

35-37	36.8%	(36.2%~37.3%)	37.5%	(36.9%~38.1%
38-40	22.9%	(22.4%~23.4%)	23.5%	(23.0%~24.0%)
41-42	11.1%	(10.6%~11.6%)	11.8%	(11.3%~12.3%
>42	3.2%	(2.9%~3.5%)	3.4%	(3.1%~3.7%)

***** Rounded (due to decimalization) prediction outcomes based on ARIMA modelling.

2. Outcomes of COVID-19 with lower economic impact

Table S12. Estimated changes in number of IVF fresh nondonor cycles over the period 2020-2023 with implications of a less severe economic decline by reducing the annual effect by 50% from the estimations of economic crisis triggered by COVID-19 by age of patients.

Age group (years)	**Without COVID-19 impact Nr. of cycles (95% CI)***		**Percentage reduction in cycles***	**With COVID-19 impact Nr. of cycles (95% CI)***		I
Year: 2020						
< 35	51,170	(43,798~58,542)	-2.58%	49,850	(42,668~57,032)	-1,32
35-37	31,358	(28,389~34,327)	-4.50%	29,947	(27,112~32,782)	-1,41
38-40	30,385	(27,296~33,474)	-1.88%	29,814	(26,783~32,845)	-57
41-42	14,924	(13,234~16,615)	-1.43%	14,711	(13,045~16,377)	-21
>42	11,923	(8,691~15,155)	-1.43%	11,753	(8,567~14,939)	-17
Total	139,760	(130,486~149,034)	-2.64%	136,075	(127,034~145,116)	-3,68
Year: 2021						
< 35	51,835	(36,545~67,126)	-4.88%	49,305	(34,761~63,849)	-2,53
35-37	32,771	(27,096~38,446)	-7.03%	30,467	(25,191~35,743)	-2,30
38-40	31,704	(25,583~37,825)	-5.10%	30,087	(24,278~35,896)	-1,61
41-42	15,469	(11,670~19,268)	-2.06%	15,150	(11,429~18,871)	-31
>42	11,935	(8,553~15,318)	-2.06%	11,689	(8,376~15,002)	-24
Total	143,714	(125,566~161,862)	-4.88%	136,698	(119,437~153,959)	-7,01
Year: 2022						
< 35	52,499	(32,207~72,792)	-6.11%	49,291	(30,238~68,344)	-3,20
35-37	34,222	(27,014~41,431)	-9.28%	31,046	(24,506~37,586)	-3,17
38-40	33,041	(25,126~40,956)	-8.40%	30,266	(23,016~37,516)	-2,77
41-42	16,034	(10,707~21,362)	-1.26%	15,832	(10,572~21,092)	-20
>42	11,913	(8,507~15,318)	-1.26%	11,763	(8,400~15,126)	-15
Total	147,709	(123,910~171,508)	-6.44%	138,198	(115,898~160,498)	-9,51
Year: 2023						
< 35	53,163	(28,878~77,448)	-7.90%	48,963	(26,597~71,329)	-4,20
35-37	35,665	(27,153~44,177)	-10.71%	31,845	(24,245~39,445)	-3,82
38-40	34,376	(24,987~43,765)	-13.21%	29,835	(21,686~37,984)	-4,54
41-42	16,603	(10,059~23,147)	-3.24%	16,065	(9,733~22,397)	-53
>42	11,883	(8,474~15,293)	-3.24%	11,498	(8,199~14,797)	-38
Total	151,690	(123,321~180,059)	-8.89%	138,206	(112,218~164,194)	-13,48

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling.

Table S13. Estimated changes in number of IVF live births over the period 2020-2023 with implication of lower economic impact triggered by COVID-19 by age of patients.

Age group (years)	**Without COVID-19 impact Live births (95% CI)***		**COVID-19 with lower economic impact. Live births (95% CI)***		**Difference (95% CI)***	
Year: 2020						
< 35	26,404	(22,593~30,214)	25,561	(21,872-29,250)	-843	(-964~-721)
35-37	11,759	(10,632~12,886)	11,006	(9,951-12,061)	-753	(-825~-681)
38-40	7,140	(6,399~7,882)	6,836	(6,126-7,546)	-305	(-336~-273)
41-42	1,761	(1,547~1,975)	1,634	(1,435-1,833)	-127	(-142~-112)
>42	405	(289~522)	374	(266-482)	-31	(-40~-22)
Total	47,470	(43,421~51,519)	45,411	(41,502-49,319)	-2,059	(-2,200~-1,918)
Year: 2021						
< 35	26,747	(18,854~34,640)	25,441	(17,934-32,949)	-1,305	(-1,691~-920)
35-37	12,289	(10,153~14,425)	11,425	(9,439-13,411)	-864	(-1,014~-714)
38-40	7,450	(6,003~8,897)	7,070	(5,697-8,444)	-380	(-454~-306)
41-42	1,825	(1,370~2,281)	1,788	(1,341-2,234)	-38	(-47~-28)

>42	406	(284~527)	397	(278-516)	-8	(-11~-6)
Total	48,718	(40,400~57,035)	46,122	(38,222-54,022)	-2,595	(-3,013~-2,178)
	Year: 2022					
< 35	27,089	(16,616~37,563)	25,434	(15,601-35,268)	-1,655	(-2,295~-1,015)
35-37	12,833	(10,123~15,543)	11,642	(9,184-14,101)	-1,191	(-1,442~-940)
38-40	7,765	(5,897~9,632)	7,113	(5,402-8,823)	-652	(-809~-495)
41-42	1,892	(1,258~2,526)	1,868	(1,242-2,494)	-24	(-32~-16)
>42	405	(283~527)	400	(279-521)	-5	(-7~-4)
Total	49,984	(38,987~60,982)	46,457	(36,158-56,756)	-3,527	(-4,226~-2,829)
	Year: 2023					
< 35	27,432	(14,899~39,965)	13,722	(13,722-36,808)	-2,167	(-3,157~-1,177)
35-37	13,374	(10,176~16,573)	9,086	(9,086-14,798)	-1,433	(-1,775~-1,090)
38-40	8,078	(5,865~10,291)	5,091	(5,091-8,932)	-1,067	(-1,359~-775)
41-42	1,959	(1,182~2,736)	1,144	(1,144-2,648)	-63	(-89~-38)
>42	404	(282~526)	273	(273-509)	-13	(-17~-9)
Total	51,248	(38,102~64,394)	34,436	(34,436-58,574)	-4,743	(-5,821~-3,666)

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling.

3. Outcomes of COVID-19 with greater economic impact

Table S14. Estimated changes in number of IVF fresh nondonor cycles over the period 2020-2023 with implication of more severe decline by increasing it by 50% of the estimations of economic crisis triggered by COVID-19 by age of patients.

Age group (years)	Without COVID-19 impact Nr. of cycles (95% CI)*		Percentage reduction in cycles*	With COVID-19 impact Nr. of cycles (95% CI)*		Difference (95% CI)*	
	Year: 2020						
< 35	51,170	(43,798~58,542)	-7.74%	47,209	(40,408~54,010)	-3,961	(-4,532~-3,390)
35-37	31,358	(28,389~34,327)	-13.5%	27,125	(24,557~29,693)	-4,233	(-4,634~-3,832)
38-40	30,385	(27,296~33,474)	-5.64%	28,671	(25,756~31,586)	-1,714	(-1,888~-1,540)
41-42	14,924	(13,234~16,615)	-4.28%	14,285	(12,667~15,903)	-639	(-712~-567)
>42	11,923	(8,691~15,155)	-4.28%	11,413	(8,319~14,507)	-510	(-648~-372)
Total	139,760	(130,486~149,034)	-7.91%	128,703	(120,127~137,279)	-11,057	(-11,755~-10,359)
	Year: 2021						
< 35	51,835	(36,545~67,126)	-14.63%	44,252	(31,198~57,306)	-7,583	(-9,820~-5,347)
35-37	32,771	(27,096~38,446)	-21.09%	25,860	(21,382~30,338)	-6,911	(-8,108~-5,714)
38-40	31,704	(25,583~37,825)	-15.30%	26,853	(21,669~32,037)	-4,851	(-5,788~-3,914)
41-42	15,469	(11,670~19,268)	-6.17%	14,515	(10,950~18,080)	-954	(-1,188~-720)
>42	11,935	(8,553~15,318)	-6.17%	11,199	(8,025~14,373)	-736	(-945~-528)
Total	143,714	(125,566~161,862)	-14.64%	122,679	(107,183~138,175)	-21,035	(-23,687~-18,383)
	Year: 2022						
< 35	52,499	(32,207~72,792)	-18.32%	42,881	(26,306~59,456)	-9,618	(-13,336~-5,901)
35-37	34,222	(27,014~41,431)	-27.84%	24,695	(19,493~29,897)	-9,527	(-11,534~-7,521)
38-40	33,041	(25,126~40,956)	-25.21%	24,711	(18,791~30,631)	-8,330	(-10,325~-6,335)
41-42	16,034	(10,707~21,362)	-3.78%	15,428	(10,302~20,554)	-606	(-808~-405)
>42	11,913	(8,507~15,318)	-3.78%	11,463	(8,186~14,740)	-450	(-578~-321)
Total	147,709	(123,910~171,508)	-19.32%	119,178	(99,843~138,513)	-28,531	(-32995~-24067)
	Year: 2023						
< 35	53,163	(28,878~77,448)	-23.70%	40,563	(22,034~59,092)	-12,600	(-18,356~-6,844)
35-37	35,665	(27,153~44,177)	-32.14%	24,202	(18,426~29,978)	-11,463	(-14,199~-8,727)
38-40	34,376	(24,987~43,765)	-39.63%	20,753	(15,085~26,421)	-13,623	(-17,344~-9,902)
41-42	16,603	(10,059~23,147)	-9.73%	14,988	(9,081~20,895)	-1,615	(-2,252~-978)
>42	11,883	(8,474~15,293)	-9.73%	10,727	(7,649~13,805)	-1,156	(-1,488~-825)
Total	151,690	(99,551~203,830)	-26.67%	111,233	(89,945~132,521)	-40,457	(-47,538~-33,376)

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling.

Table S15. Estimated changes in number of IVF live births over the period 2020-2023 with implication of greater economic impact triggered by COVID-19 by age of patients.

Age group (years)	Without COVID-19 impact Live births (95% CI)*		COVID-19 with greater economic impact. Live births (95% CI)*		Difference (95% CI)*	
	Year: 2020					
< 35	26,404	(22,593~30,214)	24,207	(20,713-27,700)	-2,197	(-2,514~-1,880)
35-37	11,759	(10,632~12,886)	9,969	(9,013-10,925)	-1,790	(-1,962~-1,619)
38-40	7,140	(6,399~7,882)	6,574	(5,891-7,257)	-567	(-625~-508)
41-42	1,761	(1,547~1,975)	1,587	(1,393-1,780)	-174	(-195~-153)
>42	405	(289~522)	363	(259-468)	-42	(-54~-30)
Total	47,470	(43,421~51,519)	42,699	(39,007-46,391)	-4,770	(-5128~-4,413)
	Year: 2021					
< 35	26,747	(18,854~34,640)	22,834	(16,096-29,572)	-3,913	(-5,068~-2,758)
35-37	12,289	(10,153~14,425)	9,698	(8,012-11,383)	-2,592	(-3,042~-2,141)
38-40	7,450	(6,003~8,897)	6,310	(5,085-7,536)	-1,140	(-1,361~-919)
41-42	1,825	(1,370~2,281)	1,713	(1,285-2,140)	-113	(-141~-84)
>42	406	(284~527)	381	(267-495)	-25	(-33~-18)
Total	48,718	(40,400~57,035)	40,936	(33,868-48,003)	-7,782	(-9,032~-6,523)
	Year: 2022					
< 35	27,089	(16,616~37,563)	22,127	(13,572-30,681)	-4,963	(-6,882~-3,044)
35-37	12,833	(10,123~15,543)	9,261	(7,305-11,216)	-3,573	(-4,327~-2,818)
38-40	7,765	(5,897~9,632)	5,807	(4,411-7,204)	-1,958	(-2,428~-1,487)
41-42	1,892	(1,258~2,526)	1,821	(1,210-2,431)	-72	(-95~-48)
>42	405	(283~527)	390	(272-507)	-15	(-20~-11)
Total	49,984	(38,987~60,982)	39,405	(30,497-48,312)	-10,580	(-12,670~-8,490)
	Year: 2023					
< 35	27,432	(14,899~39,965)	20,931	(11,368-30,493)	-6,502	(-9,472~-3,531)
35-37	13,374	(10,176~16,573)	9,076	(6,905-11,246)	-4,299	(-5,327~-3,271)
38-40	8,078	(5,865~10,291)	4,877	(3,541-6,213)	-3,201	(-4,078~-2,324)
41-42	1,959	(1,182~2,736)	1,769	(1,067-2,470)	-191	(-266~-115)
>42	404	(282~526)	365	(254-475)	-39	(-51~-27)
Total	51,248	(38,102~64,394)	37,017	(27,095-46,938)	-14,232	(-17,456~-11,007)

* Rounded (outcomes might vary ±2, due to decimalization) prediction outcomes based on ARIMA modelling.