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The Impact of COVID-19 on Fertility Rates in China: An Empirical Analysis Using ARIMA Modeling

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Abstract: This paper conducts an in-depth empirical analysis of the impact of COVID-19 on fertility rates in China using ARIMA modeling and forecasting techniques. The study reveals a significant and fundamental decline in birth rates throughout the pandemic, indicating that the long-term downward trend is more pronounced than ever. This unprecedented drop underscores the severity and uniqueness of the COVID-19 crisis's influence on reproductive behavior. The findings align with prior research on the global economic and health challenges' effects, but the scale and speed of changes during the pandemic remain unparalleled. These dynamics highlight the necessity to reassess and strengthen population management strategies and healthcare systems, particularly in reproductive health and family planning services. Despite utilizing a comprehensive dataset, limitations regarding data scope and sample size persist. Future research should broaden data scope and sample size, analyze regional differences, undertake long-term longitudinal studies, and incorporate multivariable analysis to better understand the pandemic's impact on fertility decisions.

Keywords: COVID-19 Impact, Fertility rate, ARIMA modeling, Public health, Economic uncertainty.

1. Introduction

1.1. Background

The COVID-19 pandemic has significantly affected different spheres of life for people worldwide, from public health to the economy and social organization. Through such impacts, fertility rates have been found to have varied extensively, especially in China. The response and management of the pandemic across the nation, especially with the stringent implementation of the lockdown measures, has created a topic of interest for the analysis of the birth rate during the pandemic period. This state of affairs is useful for considering the interconnection between global health emergencies and demographic shifts. It establishes the context needed to explore other social transformations triggered by such extraordinary events for humanity.

1.2. Literature Review

The correlation between demographic patterns and economic or health-related emergencies is incredibly complex and has been well-studied and proven in history [1]. Noted that economic

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recessions reduce fertility rates due to the postponement of childbearing due to economic issues common with most societies across the world and different eras. In the same vein, Goldstein et al. drive the effects of health shocks on demographics; their findings point to the fact that occurrences that cause an increase in mortality and a reduction in healthcare access also influence birth rates. Many of these changes could be attributed to a direct impact on aspects related to family planning capabilities and shifts in priorities and available resources at the societal level, thus showing how economic and health crises impact population dynamics [2]. Such studies show how socio-economic resilience or fragility, when probed at macroeconomic and healthcare stability, makes fertility behaviors quite sensitive to volatility.

The trend of reduced fertility rates in China has occurred for several decades and has been attributed to the following socio-economic factors. These social changes due to urbanization have seen women delaying childbearing due to changes in lifestyles; women have also attained primary education, hence giving priority to career advancement before going for childbearing. This has, however, been complimented by the policies enacted by the government, especially the one-child policy in the late 1970s, which hugely contributed to low birth rates [3]. The COVID-19 pandemic has added to these previously existing trends, significantly deepening the decline in fertility rates under novel economic conditions and disease risks. The COVID-19 disruption allows for rethinking decision-making processes related to family and reproduction [4]. Thus, it can offer a new lens to approach China's demographic developments in the face of a pandemic. Thus, the marriage between long-standing demographic trends and the pandemic's devastating effects provides an unprecedented chance to examine policy, autonomy, and external shocks as factors that undoubtedly control population dynamics.

Later works have offered more nuanced interpretations of this claim. Chen et al. studied the direct effect on fertility intentions and observed a change in the fertility goals of women of childbearing age in China [4]. In the dynamic environment of the pandemic, Li & Qian analyzed a more refined differentiation of changes in the intention of having a third child across different demographic groups [5]. Chu et al. revealed that the threat level related to the COVID-19 pandemic affected Chinese couples' choices regarding the number of children [6]. In addition, Zhou & Guo also employed a similar approach to explore how changes in fertility intentions may indicate an overall demographic transition in the region's core region experiencing the outbreak in China [7].

In such studies, the effects of specific economic shocks, such as the enforced periods of lockdown, have been evaluated regarding fertility intentions; the findings offer a global comparative context to some of the demographic shifts noticed in the Chinese case. A study by Mooi-Reci et al. provides the much-needed Assessment of how these economic shifts have impacted decisions on childbearing in various countries. Lockwood et al.'s report, implies that lockdown measures engendered reconsidering or delaying childbearing plans due to the increased uncertainty and economic instability. This is in line with the decline experienced in China amid similar situations. This paper also contributed to the global knowledge of demographic changes triggered by the pandemic and to the understanding of the similarities in various residents' behaviors due to the uncertain economic and social environment, thus adding to the knowledge of COVID-19's impact on reproductive behavior worldwide [8].

1.3. Objectives

This paper aims to investigate the effects of COVID-19 on fertility rates in China through estimating ARIMA models. The research aims to explore how the pandemic impacted birth rates and whether there is a likelihood of it causing long-term demographic and policy implications.

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2. Research Design

2.1. Data Sources

The data sources for this study were obtained from FRED (Federal Reserve Economic Data), managed by the Federal Reserve Bank of St. Louis. This dataset provides the annual birth rates from 1960 to 2022. Before this analysis, the data set was cleaned, and some common data treatments, such as outlier treatment and missing value treatment.

2.2. Unit Root Test

Regarding the ability of the variables to exhibit stationarity, the Augmented Dickey-Fuller (ADF) test was conducted. The results are shown in Table 1:

Table 1: Unit root test results

Data	Test Statistic (t)	p-value (p)
Ln value	-0.683	0.8510
1st order difference	-7.156	0.0000
2nd order difference	-16.650	0.0000

The results indicate that the test statistic of the original data is -0.683, with a p-value of 0.8510, suggesting that the original data has a unit root and is non-stationary. Upon performing first-order differencing, the test statistic is -7.156, with a p-value of 0.0000, indicating that the first-order differenced data does not have a unit root, making the data stationary. Further applying second-order differencing yields a test statistic of -16.650, with a p-value of 0.0000, confirming the stationarity of the data. Therefore, this part opt for second-order differencing (d=2) to ensure the data's stationarity.

2.3. ARIMA Model Setup

In order to analyze the impact of the COVID-19 epidemic on China's fertility rate, we choose to use ARIMA model for time series analysis. The ARIMA model is widely used in forecasting and analysis in fields such as economics, finance, and demographic statistics due to its ability to handle non-stationary data and high reliance on historical data. This article utilizes the ARIMA model to capture the changing trend in fertility rates and evaluate the impact of the epidemic.

The ARIMA model is commonly expressed as ARIMA (p, d, q), where p represents the autoregressive order, d represents the differencing order, and q represents the moving average order.

The autoregressive (AR) part refers to the linear relationship between the current value and past values at several time instants. For an AR(p) model, the formula is:

$$X_t = c + \sum_{i=1}^{p} \phi_i X_t - i + \epsilon t \tag{1}$$

The moving average component represents a linear combination of the current value and error terms from previous time periods. For an MA(q) model, the formula is:

$$X_t = c + \epsilon_t + \sum_{j=1}^{q} \theta_j \epsilon_t - j \tag{2}$$

In this paper, the AR model utilizes annual fertility rate data from China during the COVID-19 pandemic, while the MA model predicts future fertility rate changes using error terms.

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3. Empirical Results and Analysis

3.1. Order Determination

To determine the optimal order of the ARIMA model, we used autocorrelation function (ACF) and partial autocorrelation function (PACF) plots to identify the model parameters.

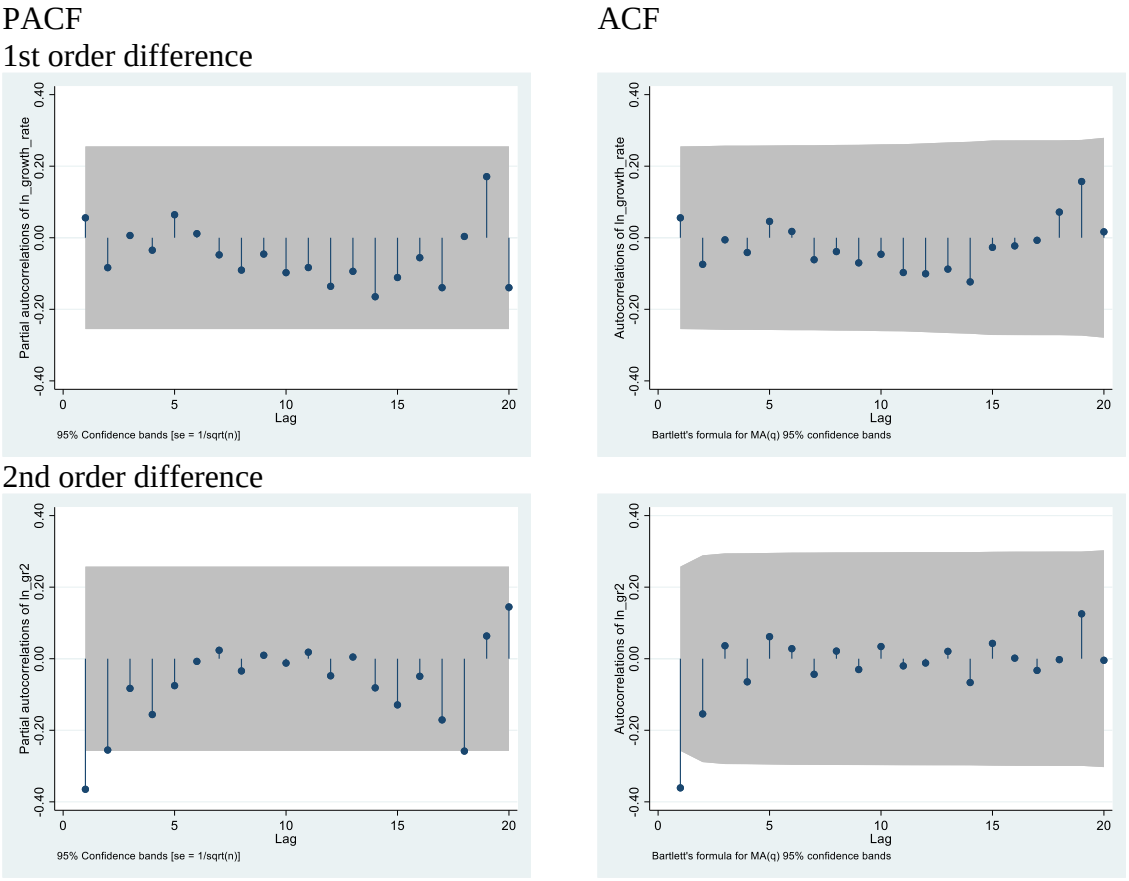

Figure 1: ARMA (p, q) identification
Photo credit: Original

From the PACF plot of the first-order difference, it is evident that there is a significant spike at lag 1, indicating the presence of a first-order autoregressive component (p=1). In the ACF plot of the first-order difference, there is a significant negative correlation at lag 1, which then gradually weakens and tends towards stability, suggesting the existence of a first order moving average component (q=1).

In the PACF plot of the second-order difference, there is still a significant spike at lag 1, further confirming the autoregressive order (p=1). The ACF plot of the second-order difference shows significant correlation at lag 1, which then gradually decreases, also indicating the presence of a first-order moving average component (q=1).

Therefore, the ARIMA (1,2,1) model was chosen for the work to describe the fluctuations in fertility rates in China over the period studied. This model effectively captures the changing trend of the fertility rate data and can be used to predict the impact of the COVID-19 pandemic on the fertility rate.

After establishing the ARIMA model, in order to ensure the applicability and accuracy of the model, it is necessary to examine the residuals of the model. This study uses the Portmanteau (Q) statistic to test the residuals of the ARIMA (1, 2, 1) model.

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The results are as follows:

Table 2: Residual Tests for ARIMA Model

Model	Portmanteau (Q) Statistic	Prob > Chi²
Birth rate – ARIMA (1,2,1)	5.5905	0.9993

The Portmanteau Q-statistic is 5.5905 with a corresponding p-value of 0.9993. Due to the p-value being significantly greater than 0.05, we cannot reject the null hypothesis of residuals being white noise, indicating that the model residuals are not significantly autocorrelated, suggesting a good fit of the model to the data. So we have confirmed the effectiveness and reliability of the ARIMA(1, 2, 1) model, which can be further used to predict the impact of the COVID-19 pandemic on the fertility rate.

3.2. Forecast Results and Interpretation

The fundamental assumption of this article is to utilize data from before the COVID-19 pandemic to predict a "control group" unaffected by the pandemic, while considering the fertility rates in the real world as the experimental group.

The predictions of the ARIMA model (1,2,1) were specifically examined for the years 2020 to 2022, with specific attention to the effect of COVID-19 on the TFR in China, which was assiduously assessed. In these years, the model assumed a decline in birth rates, which can be attributed to the pandemic that started in and affected the global community.

Table 3: Forecasted vs. Actual Birth Rates

Year	Actual Birth Rate	Predicted Value	Difference	% Change
2017	12.64	-	-	-
2018	10.86	-	-	-
2019	10.41	-	-	-
2020	8.52	10.024	-1.504	-15.00%
2021	7.52	9.64696	-2.12696	-22.05%
2022	6.77	9.27636	-2.50636	-27.02%

The counter also adequately characterized the steep drop in 2020 as lockdown measures were stringent, and there was much societal insecurity, which may have led to delayed or, perhaps, a complete abandonment of childbearing plans. This trend has continued in 2021 and 2022, which means that the demographic behavior shift discussed would not be solely a direct effect of the pandemic but a possible long-term change.

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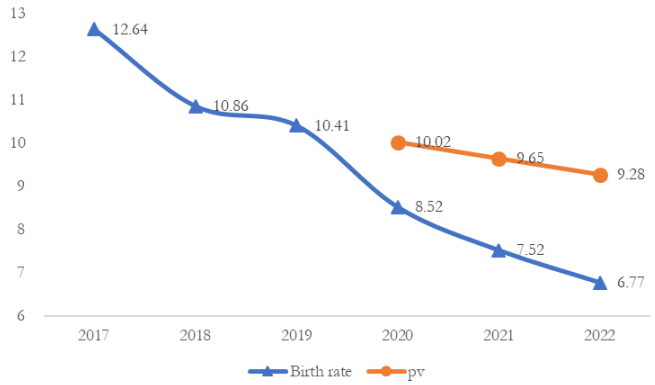

Figure 2: Birth rate before and after Covid-19 in China
Photo credit: Original

Figure 2 illustrates the changes in birth rates in China before and after the COVID-19 pandemic. The blue line in the graph represents the actual birth rate, while the orange line indicates the predicted birth rate (pv). The graph illustrates a sharp decline in the birth rate starting from 2020. This birth rate chart from 1960 to 2022 notably highlights the data for 2020 and 2021, indicating a significant decrease in birth rates at the onset of the COVID-19 pandemic. This phenomenon is particularly pronounced compared to the gradual declines recorded in the past few decades [9]. Prior to 2020, birth rates were generally decreasing due to socio-economic transitions, including urbanization, increased education, and China's one-child policy [3]. However, the COVID-19 pandemic abruptly disrupted this trend. In fact, the birth rate in 2020 dropped to 8.18 per 100,000 people, a decrease of about 30% compared to 10.41 in 2019. Even in 2021 and 2022, the birth rate continued to decline further to 7.52 and 6.77 respectively

That is, the deviations seen in recent years are considerably higher than what history has pointed to, even when controlling for bearish trends. This means that even after the pandemic's emergence, the trend is progressing instead of regression. It shows a dramatic decline around the same periods of the rising economic uncertainties and the change in social culture resulting from the mental effects of the COVID-19 pandemic concerning family planning. These and the conditions that escalated the pandemic point to fertility rate reductions quickening and lasting more than the health threat.

The ability of the ARIMA model to capture this anomaly supports the use of the method in forecasting, particularly under shifted conditions. The model, as usually working on the data to judge by, has pointed at a change, which the virus’s presence signals as deep and potentially permanent.

Thus, the information presented in this paper is valuable for policymakers and health authorities. By considering the degree and the speed of the change in birth rates, one can better adapt the public health initiatives, the economic courses and social programs that define societies to this new demographic reality [10].

4. Discussion

These outcomes conform to the findings of other studies that examine the consequences of economic and health quandaries on birth rates. Sobotka et al. stated that economic recessions, analyzed by Sobotka et al., are the most typical factors affecting fertility, while Goldstein et al. mentioned that health crises could also be considered a contributing factor to changes in fertility, as seen in Goldstein et al.. Thus, while prior years have seen lower rates of births in China, they have stabilized or increased; however, the dramatic drop in birth rates during the COVID-19 pandemic exceeds previous

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episodes, and this is consistent with the findings of other recent studies by Chen et al. and Zhou & Guo indicating similar and unprecedented effects [4, 7].

The type of demographic changes occurring during pandemics is well elucidated in this analysis to the effect that correct healthcare and economic policies must be implemented to counter such changes [11]. In addition, the drastic and prolonged fall in birth rates points towards some possible long-term demographic problems. Other works by Mooi-Reci et al. and Luppi, Arpino, and Rosina further envision how the socio-economic changes brought by COVID-19 affect fertility intentions and aspirations and extend the observations in this paper regarding long-term effects [8, 12].

This work should be a wake-up call for any policymaker or futurist when planning for any other epidemic in the future. Based on the studies by Alaimo et al. and Guetto et al. that describe the changes in the population in the post-covid era, it is essential to outline that economic security, healthcare, and childcare policies can help adjust the trends and minimize the negative effects on the proc motivational factor for fertility [13].

An appreciation of these demographic effects is particularly necessary in delivering health services, given the prediction of future health needs. Understanding the extension of COVID-19 straight to influencing women's reproductive health systems provides the day-to-day practical implication in patient care and directing resources from Phelan, Behan, and Owens and Blumenfeld as tangible sources of information [9, 14].

5. Conclusion

To sum up, this paper has offered an elaborate empirical analysis of the effects of COVID-19 on fertility in China using ARIMA modelling and forecasting techniques for the pandemic's impact on demographic patterns. According to the data presented in the study, the birth rates have significantly and fundamentally decreased throughout the pandemic, which means there is a further authoritative trend of a long-term decline in birth rates. This decline is sharper than previous trends indicate, demonstrating the COVID-19 crisis's distinctiveness and severity's influence on fertility tendencies.

They also align very well with prior research on the global challenges impacting the economy and health, as well as their effects on fertility. However, during the COVID-19 pandemic, the scale and rapidity of this process have been unprecedented. These dynamics underscore the importance of reevaluating and enhancing existing population management strategies and healthcare systems, particularly in reproductive health and family planning services, requiring collaboration among decision-makers, healthcare workers, and providers. The application of economic theories such as Public Choice Theory and Welfare Economics can assist in formulating effective public policies to address the long-term population challenges brought about by the pandemic.

Although this article utilizes a comprehensive dataset, limitations in the data scope and sample size remain. Future research could enhance findings by broadening the data range and increasing the sample size. Additionally, variations in fertility trends across different regions may exist. Subsequent studies could further segment regions to analyze specific circumstances, thus providing more targeted policy recommendations. In addition, considering the long-term effects of the pandemic, it is essential to conduct extended longitudinal studies. This will assist in observing the sustained impact of the pandemic on fertility rates and evaluating the long-term effectiveness of current policies. Multivariable analysis also represents a critical avenue for future research. Incorporating additional variables, such as economic conditions, policy changes, and social psychology, can lead to a more comprehensive understanding of the pandemic's influence on fertility decisions.

References

[1] *Sobotka, T., Skirbekk, V., & Philipov, D. (2011). Economic recession and fertility in the developed world. Population and Development Review, 37(2), 267-306.*

DOI: 10.54254/2754-1169/115/2024BJ0195

[2] *Goldstein, J. R., Kreyenfeld, M., Jasilioniene, A., & Örsal, D. K. (2013). Fertility reactions to the "Great Recession" in Europe: Recent evidence from order-specific data. Demographic Research, 29, 85-104.*

[3] *Hesketh, T., Lu, L., & Xing, Z. W. (2005). The effect of China's one-child family policy after 25 years. New England Journal of Medicine, 353(11), 1171–1176.*

[4] *Chen, T., Hou, P., Wu, T., & Yang, J. (2022). The impacts of the COVID-19 pandemic on fertility intentions of women of childbearing age in China. Behavioral Sciences, 12(9), 335.*

[5] *Li, Z., & Qian, S. (2023). The impact of COVID-19 on the intention of third-child in China: an empirical analysis based on survey data. BMC Public Health, 23(1), 1195.*

[6] *Chu, K., Zhu, R., Zhang, Y., Pang, W., Feng, X., Wang, X., ... & Li, W. (2022). Fertility intention among Chinese reproductive couples during the COVID-19 outbreak: a cross-sectional study. Frontiers in Public Health, 10, 903183.*

[7] *Zhou, M., & Guo, W. (2023). Sooner, later, or never: Changing fertility intentions due to Covid-19 in China's Covid-19 epicentre. Population Studies, 77(1), 123–140.*

[8] *Mooi-Reci, I., Trinh, T. A., Vera-Toscano, E., & Wooden, M. (2023). The impact of lockdowns during the COVID-19 pandemic on fertility intentions. Economics & Human Biology, 48, 101214.*

[9] *Phelan, N., Behan, L. A., & Owens, L. (2021). The impact of the COVID-19 pandemic on women's reproductive health. Frontiers in endocrinology, p. 12, 642755.*

[10] *Batiha, O., Al-Deeb, T., Al-zoubi, E. A., & Alsharu, E. (2020). Impact of COVID-19 and other viruses on reproductive health. Andrologia, 52(9), e13791.*

[11] *Alaimo, L. S., Ciommi, M., Vardopoulos, I., Nosova, B., & Salvati, L. (2022). The medium-term impact of the COVID-19 pandemic on population dynamics: The case of Italy. Sustainability, 14(21), 13995.*

[12] *Luppi, F., Arpino, B., & Rosina, A. (2022). Fertility plans in the early times of the COVID-19 pandemic: The role of occupational and financial uncertainty in Italy. Plos one, 17(12), e0271384.*

[13] *Hansson, S., Orru, K., Torpan, S., Bäck, A., Kazemekaityte, A., Meyer, S. F., ... & Pigrée, A. (2021). COVID-19 information disorder: Six types of harmful information during the European pandemic. Journal of Risk Research, 24(3-4), 380-393.*

[14] *Blumenfeld, Z. (2020). Possible impact of COVID-19 on fertility and assisted reproductive technologies. Fertility and sterility, 114(1), 56-57.*