Gender Inequality in Education and its Indirect Impact on Economic Growth through Vital and Demographic Variables in Chile

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Abstract

This study analyzes the indirect effects of gender inequality in education on economic growth in Chile, mediated through life expectancy at birth, infant mortality, and the total fertility rate. We rely on panel data from the 15 Chilean regions during the period 1990-2022, employing an econometric approach with Fixed Effects and Two-way models. The research is framed within Sustainable Development Goals (SDGs) 4, 5, and 10, emphasizing the relevance of incorporating a gender perspective in public policy analysis. The results show that gender inequality in education significantly affects these indicators, which in turn influence economic growth, highlighting the importance of inclusive educational policies to promote economic well-being.

Keywords: Gender inequality in education, infant mortality, life expectancy, total fertility rate, economic growth.

1. Introduction

Women's education plays a crucial role in human and economic development. Amartya Sen, Nobel laureate in Economics, emphasizes the importance of access to education and healthcare in improving quality of life, especially for women [1]. An educated woman is empowered, actively participates in family and community decisions, and contributes significantly to economic growth through human capital. Moreover, literature highlights that female education is linked to a reduction in fertility, infant mortality, and an increase in life expectancy at birth.

Recent research has deepened the analysis of gender inequality in education and its economic impact. In previous studies, we addressed the direct effect through human capital accumulation, and this work is a continuation of that [2], focusing on the indirect effect. Life expectancy at birth, infant mortality, and the total fertility rate are key indicators mediating the impact of education on economic growth. Knowles, Lorgelly, and Owen [3] and Lagerlöf [4] have shown that female education has a positive effect on production, but they also demonstrated that gender inequality in education can be a significant obstacle to economic development. For instance, high initial levels of gender inequality in education can lead to high fertility rates and low economic growth, creating a poverty trap that justifies public intervention.

Numerous studies confirm the relationship between female education and better child health. Hill and King [5] and Murthi, Guio, and Dreze [6] note that women's education has a significant impact on reducing infant mortality. Summers [7] emphasizes that investing in women's education yields high returns in terms of child health. Moreover, research by Barro and Lee [8] and King and Mason [9] indicates that greater female education leads to lower fertility rates, which favors long-term economic growth. Klasen [10] and Knowles, Lorgelly, and Owen [3] also find a positive correlation between female education and life expectancy at birth.

This study focuses on the Chilean regions and aims to identify and quantify the effect of gender inequality in education on life expectancy at birth, infant mortality, and the total fertility rate—variables that explain regional growth differences [2,11]. Based on panel data from the 15 Chilean regions during the 1990–2022 period, the econometric analysis will employ Fixed Effects and Two-way models. This work is framed within Sustainable Development Goals (SDGs) 4, 5, and 10 and contributes to a deeper understanding of how educational and gender policies are crucial for the development of territories and sustainable economic growth by improving the vital statistics of the regions. It aims to contribute to the existing literature with a regional focus, highlighting the importance of inclusive educational policies to promote economic well-being in Chile.

2. Theoretical Framework

2.1. Importance of Women's Education: Direct and Indirect Effects

A country that achieves access to education and healthcare for all its citizens, even with low income, can achieve good results in terms of quality of life [1]. Sen emphasizes that education can have a more important effect on quality of life than other factors associated with a country's wealth. The role of women's education is particularly relevant. An educated woman is more empowered, can participate in decision-making at the family and community levels, has greater economic independence, gains more property rights and status, and improves her general position in social culture (pp. 264–265). Additionally, women's education has significant effects on development. Greater education allows women to participate in paid activities, increasing the country's income through human capital.

Klasen [10] emphasizes that theoretically, if it is assumed that boys and girls have innate abilities that are similarly distributed, and that those with more abilities are more likely to receive education, gender inequality in education means that less capable boys than girls have the opportunity to be educated. As a result, the innate ability of educated boys is lower than it would be if both boys and girls had the same opportunity. Assuming that human capital combines innate abilities and education, gender inequality would reduce growth by diminishing potential human capital. This is called the direct effect of gender inequality in education on economic growth, and according to the author, this effect is also empirically demonstrated. Following this line, more educated women contribute to the increase of human capital in the next generation, improving both the quantity and quality of their children's education, and consequently, positively affecting economic growth [8,9,10,12].

The total effect of women's education and, consequently, gender inequality in education on growth comes from the sum of direct and indirect effects. These indirect effects are relevant for the development and quality of life of the population, which is why it is important to study them. The main or most developed ones in the literature are: infant mortality, fertility, and thus population growth, and life expectancy at birth.

2.2. Infant Mortality

Infant mortality, according to Sen and Brundtland [13], is the greatest example of a lack of freedom, as the things a person wishes to do can only be achieved with life, and thus, an early death is a basic denial of human freedom.

Several studies demonstrate that the education gap between men and women has repercussions on infant mortality. Countries with greater educational equity tend to have lower infant mortality rates and healthier populations [7,8,5,6,10]. Various studies conclude that women's education has a more powerful effect on social welfare than the income or education of the father. Considering that fathers and mothers have different preferences regarding family decisions and different income sources, the degree of participation of the mother in decisions may influence the level of resources invested in the children's education and health. It is understood that women tend to invest more in favor of children's health and the family in general [7,5].

Summers [7] emphasizes that investment in women's education yields the highest return in developing countries, helping to break the vicious cycle where greater ignorance leads to poverty, which in turn leads to higher infant mortality and fertility rates. Conversely, more educated women favor demographic situations as well as the health and happiness of their families. According to King and Mason [9], a mother's education positively influences children's nutrition and immunization. The study reveals that, according to the latest demographic and health surveys in over 40 developing countries, the mortality rate of children under five is lower in households where the mother has primary education than in households where the mother has no education, and much lower in those where the mother has secondary education. Similar results are obtained when assessing children's immunization rates.

Murthi et al. [6], in their study of 296 districts in India, sought the factors impacting infant mortality and fertility. The results demonstrate that both male and female literacy have a broad negative effect on infant mortality, but only female literacy was statistically significant. The study also shows that other development variables such as male literacy, poverty reduction, urbanization, and access to medical facilities, although having positive effects on child survival, are relatively small compared to the effect of female literacy. Finally, it is also concluded that greater gender inequality tends to reduce women's power in society and thus negatively affect children's health and survival. This is understood in the same way as in Summers [7] and Hill and King [5], where children's health in India largely depends on women's initiative.

The empirical analysis of Hill and King [5] evaluated the effect of both women's education and gender inequality in education on social variables related to quality of life and growth. They concluded that an increase in primary education for women by 10 percentage points could translate into a reduction in infant mortality of around 4.1 deaths per 1,000 births. In the case of secondary education, the reduction could reach 5.6 deaths per 1,000 births. These results are obtained even when controlling GDP and other variables associated with infant mortality.

In 2004, Abu-Ghaida and Klasen [14] calculated the costs of not meeting one of the specific objectives proposed by the global community at the Millennium Summit to promote gender equity. This goal was to equalize primary and secondary schooling for men and women by 2005. Projections showed that countries far from meeting the proposed goal in 2005 would have reductions in their per capita

GDP of 0.1 to 0.3 percentage points. By 2015, it was estimated that the infant mortality rate would be higher by 14 per 1,000 for children under five. Similarly, higher rates of low-birthweight infants were projected (2.4 percentage points).

Finally, according to the United Nations Educational, Scientific and Cultural Organization (UNESCO) [15], if all women received secondary education, infant mortality would be reduced by half.

2.3. Fertility and Population Growth

Women's autonomy increases with schooling, contributing to lower fertility rates [1]. Several empirical studies demonstrate the relationship between women's education and lower fertility rates, which translates into slower population growth, favoring economic growth [8,7,5,6,10,14,16]. The latter authors reveal that university education in the 1980s encouraged women to adopt non-traditional attitudes towards marriage and motherhood. It is expected that increasing both the quality and quantity of education, particularly for women, will reduce fertility, both by increasing the opportunity cost of children and by giving women greater control over their motherhood [17]. Goldin [18] refers to the fact that most of the current wage disparities between men and women occur within the same occupation, and at the same time, these disparities emerge primarily with the birth of the first child. All of the above causes a rethinking of motherhood, affecting current fertility rates.

Low fertility rates, in turn, would affect future dependency rates, increasing per capita income and reducing poverty [19]. In this regard, the empirical analyses of Bloom and Williamson [20] and Klasen and Lamanna [21] indicate that population growth has a purely transient effect on economic growth. This effect occurs only when the working-age population and dependent population grow at different rates. That is, if the working-age population grows faster than the dependent population, there will be a positive effect on economic growth, which the authors call the 'demographic gift.' The above coincides with the studies of Bloom, Canning, and Sevilla [22] and Canning et al. [19], who note that beyond population growth, changes in the age structure of the population pyramid are what affect economic growth, which can be positive, negative, or neutral according to the authors.

Barro and Lee [24,8] evaluate the effect of education on variables that influence economic growth, such as fertility. The model used the logarithm of the total fertility rate for the period between 1965 and 1985 as the dependent variable, and years of female and male schooling, among other variables, as explanatory variables. The results show that the effect of education on fertility is different for men and women. In less developed countries, more female education leads to lower fertility rates, the opposite for men. In more developed countries, with higher educational levels, these results are reversed. In this regard, Dao et al. [23] highlight that improving gender equality in education increases the opportunity cost of raising children, thus reducing fertility.

Among the set of variables included in the study by Murthi et al. [6], only female literacy and women's participation in the labor force had a significant effect on fertility. Both effects were negative, meaning that greater agency or empowerment of women leads to lower fertility rates. The authors state that educated mothers are able to plan their families and thus decide how many children they wish to have, thanks to their greater knowledge and control over modern contraceptive methods. Referring to this work, Sen [1, p. 265] mentions, 'economic development may fall short of being "the best contraceptive," but social development—especially women's education and employment—can be very effective.

Several authors report that not only women's education but also the gender gap in schooling have a negative effect on fertility rates.

3. Materials and Methods

This section will detail the data sources and methods used to analyze the impact of gender inequality in education on key indicators such as life expectancy at birth, infant mortality, and the total fertility rate in Chilean regions.

3.1. The Data

This study uses the database structured in a previous work [2], which addressed the direct effect of gender inequality in education on economic growth. The database was built using secondary data sources, such as the National Socioeconomic Characterization Survey (CASEN), the Central Bank of Chile, and the National Institute of Statistics. These sources provide reliable, gender-disaggregated data, essential for a detailed and differentiated analysis of the realities of men and women in the educational, economic, and demographic contexts in Chile.

Table 1 provides a descriptive statistical analysis of various variables in a panel data set, broken down into three components: overall, between, and within. The analysis shows how these variables vary between regions and within each region over time.

For example, the schooling ratio (ratioesci), which shows the difference in average years of schooling between women and men, has an overall mean of 0.96, with low variability within regions, lower than other educational variables such as the secondary schooling ratio or average or higher schooling levels of men and women. The average life expectancy in the Chilean regions is 77.36 years; the average total fertility rate is 2 children per woman, just below the replacement rate of 2.1. On the other hand, the average infant mortality rate is 7.84 deaths per 1,000 births. This last variable shows the greatest differences between regions in the country. Finally, the logarithm of initial GDP per capita (8.72) shows stability across regions, reflected in its low variability.

Table 1: Descriptive Analysis of the Main Study Variables.

Variable	Statistic	Mean	Std. Dev.	Min.	Max.	Variable	Statistic	Mean	Std. Dev.	Min.	Max.
	overall	2.87	2.66	4.21	11.69		overall	12.49	4.69	5.01	26.3
tcaapibpc	between	2.84	1.12	0.81	5.31	escsuppromh	between	12.66	3.2	7.96	20.21
	within		2.24	-6.47	7.42		within		3.48	-6.97	9.09
	overall	8.72	0.54	7.64	10.16		overall	75.31	4.01	66.36	80.62
lnpibibi	between	8.71	0.45	8.06	9.91	evivi	between	75.56	1.5	73.82	78.84
	within		0.27	-0.7	0.57		within		3.83	-7.69	5.09
	overall	0.96	0.03	0.91	1.06		overall	9.95	4.64	5.84	26.6
ratioesci	between	0.96	0.02	0.94	1.02	ml_l	between	9.71	1.59	6.37	12.75
	within		0.02	-0.04	0.04		within		4.25	-5.8	13.85
	overall	9.37	1.07	7.13	11.37		overall	2.22	0.36	1.72	3.26
escpromf	between	9.42	0.84	8.32	10.75	tgfin	between	2.21	0.18	1.88	2.52
	within		0.73	-1.29	1.23		within		0.32	-0.44	0.83
	overall	9.74	1.18	7.18	11.9		overall	-0.48	3.84	-9.21	6.8
escpromh	between	9.79	1.02	8.2	11.19	vardesempl	between	-0.59	1.04	-2.83	0.85
	within		0.66	-1.21	1.18		within		3.9	-6.78	7.59
	overall	12.03	4.33	4.6	24.71		overall	17.13	12.78	1.2	40.7
escsuppromf	between	12.2	2.32	9.12	17.71	pctpoblru	between	17.21	12.79	1.52	34.97
	within		3.76	-7.38	8.48		within		2.13	-4.85	7.11

3.2. Methodology

As explained in the previous section, we will work with the database previously constructed, using three distinct dependent variables, which will be explained by GDP per capita, the schooling of men and women, and gender inequality in education (average, secondary, or higher schooling ratio). For the analysis, Fixed Effects and Two-way models will be applied. Two-way models allow for capturing variations both between regions and over time, which is crucial to understand how female education influences economic growth in different temporal and regional contexts.

We work with the period from 1990 to 2022, divided into six sub-periods: 1990-1996; 1996-2003; 2003-2009; 2009-2013; 2013-2017; and 2017-2022. Therefore, the final variables represent the last year of each period, while the initial variables represent the first year of each period. In this way, we analyze causality between the studied variables. The general formula for the Two-way model is as follows:

$$Yi,t = \gamma_i + \beta_1 GDPpc_{i,t-1} + GIE_{i,t-1} + + \delta_i + \epsilon_{i,t} \quad (1)$$

Where:

Yi,t = Infant Mortality, Life Expectancy, or Total Fertility Rate of region *i* at the end of period *t*.

GDPpci,t-1 = Natural logarithm of GDP per capita of region *i* at the beginning of period *t* (end of period *t–1*).

GIEi,t-1 = Variable representing gender inequality in education in region *i* at the beginning of period *t* (end of period *t–1*).

EDUCi,t = Average education by gender in region *i* during period *t*.

γi = Vector of dummy variables for each region (represents fixed regional effects).

δ = Vector of dummy variables for each period (represents fixed time effects).

β = Coefficient of the predictor variable.

εi,t = Error term.

In the analysis of the models, several validation techniques were implemented to ensure the robustness and reliability of the results obtained. One of the fundamental tests used was the Hausman Test, which determines the consistency and efficiency of random effects compared to fixed effects. When the result of this test is significant, it suggests that the fixed effects model is more appropriate. Conversely, if the result is not significant, it indicates that the random effects model is suitable for the case at hand.

To compare models, the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC) were used. These criteria help assess the quality and fit of the models, where lower values indicate a better balance between model fit and complexity. A model with lower AIC and BIC values is preferred, as it suggests better performance without overfitting the data.

Finally, robust standard errors were applied to correct potential issues of heteroskedasticity and autocorrelation in the data. This allowed for more reliable coefficient estimates, ensuring that the conclusions drawn from the analysis were sound and based on accurate data. These validation techniques, integrated into the methodology, guarantee that the models used are appropriate and that the results obtained are robust and reliable for interpretation and informed decision-making.

4. Estimations and Results: Vital Variables as Dependent Variables

Two-way econometric models and various tests will be employed to ensure the robustness of the results. This approach will help uncover the indirect effects of female education on regional economic growth, providing a deeper understanding of how educational and gender policies can promote development.

The following three tables present evidence on the effect of gender inequality in education, as well as the individual effect of the schooling of men and women on two vital variables: infant mortality (IM) and life expectancy (LE); and one demographic variable: the total fertility rate (TFR). These variables were previously demonstrated to be determinants for understanding growth differences between Chilean regions. Our prior study [2] showed that, for Chile, higher infant mortality reduces growth, while life expectancy is positively related to growth. On the other hand, unlike what usually happens in developing countries, in Chile, the total fertility rate positively impacts economic growth, which is closely related to the population aging process in the country, as is the case in developed countries.

The goal of this work is not to find the best model to explain the three previously mentioned variables but to present the best estimations incorporating our main study variables, which are gender inequality in education and schooling. The Two-way fixed effects model (controlled for heteroscedasticity and autocorrelation) is used. Through a restrictive F-test, it is confirmed that it is better to use a Fixed Effects model rather than estimate by Ordinary Least Squares. Likewise, the Hausman test was applied, which showed that for each equation, Fixed Effects (FE) were more efficient than a Random Effects (RE) model.

Table 2 (FE model) and Table 3 (Two-way model) use the Total Fertility Rate (TFR) at the end of each period as the dependent variable. Following the example of Barro and Lee [8], various squared variables are tested to see if there is a nonlinear relationship between initial GDP per capita and average schooling on the TFR. These authors also propose that TFR is linked to both LE and IM. As mentioned in Section 2, higher LE would make having children more attractive but also imply that fewer births are required to generate a certain number of children who survive into adulthood. Meanwhile, higher IM implies greater costs in raising children, discouraging fertility, but at the same time increasing the number of births needed to achieve a certain number of survivors.

Table 2: Dependent Variable: Total Fertility Rate (TFR), Fixed Effects (FE) Model.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnpibibi	−0.7793***	−0.3263*	−0.2952*	−0.3753**	−0.3550**	−0.3041*
ratioesci	−35.0407	–	−43.7356*	–	−38.5393	−42.4702
ratioesci2	17.7792	–	23.3295*	–	20.3522	22.6128
escsupromf	-	−0.0380***	−0.0405***	-	-	−0.0302
escsuppromh	–	–	–	−0.0393***	−0.0405***	−0.0109
varev	−0.0011	−0.0250**	−0.0213*	−0.0240**	−0.0209**	−0.0215*
varmi	−0.0369***	−0.0378***	−0.0373***	−0.0383***	−0.0378***	−0.0374***
R^2	0.7707	0.8642	0.8717	0.8637	0.8681	0.8722
Adjusted R^2	0.756	0.8573	0.8617	0.8568	0.8578	0.8605
AIC	−51.7775	−97.774	−98.5754*	−97.4766	−96.2313	−96.9139
BIC	−39.6234	−88.0508*	−83.9905	−87.7534	−81.6464	−79.8981

The results under the FE model show that regions with higher initial GDP per capita also have lower fertility rates (no quadratic relationship is observed). According to Barro and Lee [8], countries with higher income levels tend to substitute quality for quantity of children, and there is greater awareness of birth control. Apparently, this also applies to Chilean regions.

The secondary school enrollment ratio shows a significant quadratic effect on the TFR. This result is consistent across all models. It is also observed that both the variation in infant mortality and life expectancy are negatively related to TFR. Furthermore, there is a negative, consistent, and significant relationship between higher education—both for women and men—and TFR. However, in both cases, this significance disappears in the presence of the gender equality in education variable. Our findings differ from those of Barro and Lee [8], who found different results for men and women.

Table 3 (Two-Way Model) shows that GDP per capita loses significance in the presence of time variables. Models I and VI perform best, as they present the lowest values of the Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), indicating they are the most efficient and best-fitting models.

The models confirm the relationship between gender inequality in education and fertility. In Model I, the parameter for the school enrollment ratio shows a coefficient of -24.67, indicating that an increase in this ratio is associated with a significant decrease in regional total fertility rate. On the other hand, the coefficient for the squared enrollment ratio (ratioesci2) is 13.12, suggesting a quadratic relationship where the fertility rate decreases up to a certain point of the enrollment ratio and then begins to rise. This reflects the existence of a turning point in the relationship between education and fertility. From a certain level of equality (approximately 0.94), fertility rates begin to increase, which is currently beneficial for the growth of Chilean regions.

Finally, regarding fixed time effects, the F-test for the joint significance of the time variables in the model confirms their relevance. It is observed that fertility rates in Chilean regions have been decreasing over time, showing a notable decline in recent years [25,26] regarding the demographic transition process in Chile. In these equations, gender equality in education proves to have a greater impact on the TFR than male and female schooling individually.

Table 3: Dependent Variable: Total Fertility Rate (TFR), Two-Way Model.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnpibibi	0.1544	0.1138	0.1273	0.0715	0.0874	0.1121
ratioesci	−24.6726**	-	−28.8666**	-	−25.8010*	−28.1341*
ratioesci2	13.1234**	-	15.3284**	-	13.6191*	14.9108**
escsupromf	-	−0.0182	−0.0196	−0.0184	−0.0179	−0.0144
escsuppromh	-	-	-	-	-	−0.0060
1996–2003	−0.4705***	−0.4240***	−0.4105***	−0.4201***	−0.4136***	−0.4074***
2003–2009	−0.8275***	−0.7295***	−0.7202***	−0.7225***	−0.7229***	−0.7138***
2009–2013	−0.7685***	−0.6140***	−0.6124***	−0.6029***	−0.6132***	−0.6019***
2013–2017	−0.9551***	−0.7360***	−0.7296***	−0.7190***	−0.7308***	−0.7145***
2017–2022	−1.2383***	−0.9189***	−0.9133***	−0.9188***	−0.9380***	−0.8992***
R^2	0.9417	0.9437	0.9465	0.944	0.9459	0.9466
Adjusted R^2	0.9355	0.9386	0.94	0.9389	0.9393	0.9393
AIC	−160.8145	−165.8081	−166.0456	−166.2556*	−165.1091	−164.2517
BIC	−141.368	−148.7923	−144.1683	−149.2399*	−143.2318	−139.9436

Tables 4 and 5 use infant mortality (IM) at the end of each period as the dependent variable. In both cases, we observe a negative relationship between GDP per capita and infant mortality (IM), meaning that higher income levels reduce the mortality rate of children under one year of age.

Table 5 also included the variable LN(GDPpc_i)^2, revealing that the effect of GDP per capita on IM is nonlinear. This is an unconventional result, influenced solely by the Antofagasta region—a mining region that, although it has the highest GDP per capita each year, has experienced a slower reduction in infant mortality compared to other regions, particularly during the periods 1996–2003 and 2003–2009. If these two observations are removed, the results do not change significantly, except that GDP per capita no longer has a quadratic effect and remains consistently negative. In other words, income contributes to lower infant mortality rates.

Table 4: Dependent Variable: Infant Mortality (IM), Fixed Effects (FE) Model.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnpibibi	−6.5850***	−5.7210***	−5.7934***	−6.0389***	−6.1017***	−5.6437***
ratioeseci	38.9014	-	43.6045	-	41.6366	42.5605
ratioeseci2	−22.2129	-	−24.7209	-	−23.7124	−23.7751
escpromf	-	−0.2106	−1.2667	-	−0.7040	−8.5327
escpromf2	-	−0.0004	0.0515	-	−0.0259	0.3584
escpromh	-	-	-	0.5839	-	7.1877
escpromh2	-	-	-	−0.0361	−0.2885	−0.2885
R^2	0.717	0.702	0.720	0.7013	0.7182	0.7254
Adjusted R^2	0.7064	0.6908	0.702	0.6901	0.7001	0.7001
AIC	267.6843*	272.0198	270.7865	272.201	271.324	273.1414
BIC	274.9768*	279.3123	282.9406	279.4934	283.478	290.1571

A quadratic effect between gender equality and infant mortality is also observed. This means that, beyond a certain level of equality, it contributes to reducing infant mortality rates. These variables are only significant in the Two-Way models.

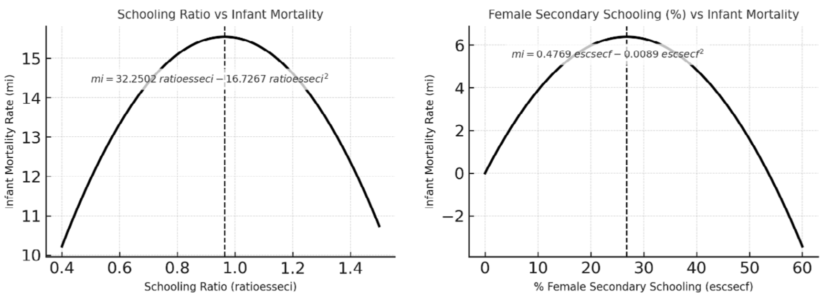
Models III to IV (Table 5) are those with the lowest AIC and BIC values. For example, Model III shows that the initial school enrollment ratio (ratioesci) has a coefficient of 32.25, and its square ($ratioesci^2$) has a coefficient of -16.72, indicating a quadratic relationship in which infant mortality increases with the enrollment ratio up to a turning point (0.96), after which it decreases (see Graph 1). In other words, regions with greater gender equality in education show lower infant mortality rates.

Similarly, the initial percentage of female secondary schooling has a turning point (26.79%), after which it also has the expected effect on infant mortality. Models that analyze the individual effect of male schooling reveal similar results.

Table 5: Dependent Variable: Infant Mortality, Two-Way Model.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
lnpibibi	−4.6009	−16.3321**	−19.0289**	−25.3973**	−27.8718**	−27.0797**
lnpibibi2	0.1825	0.8234**	0.9633**	1.3428**	1.4675**	1.4132**
ratioeseci	34.1750*	–	32.2502*	–	30.5233*	30.1049*
ratioeseci2	–	–	−16.7267*	–	−15.9433*	−15.8618*
escsecfi	–	0.4769**	0.4227**	–	–	0.3025
escsecfi2	–	−0.0091**	−0.0084**	–	–	−0.0056
escsech	–	–	0.4899**	0.4899**	0.4841**	0.2484
escsech2	–	–	−0.0095***	−0.0095***	−0.0092**	−0.0052
1996–2003	−4.0126***	−3.9599***	−3.8709***	−3.7683***	−3.7518***	−3.7494***
2003–2009	−4.3815***	−4.4618***	−4.2143***	−4.0972***	−4.0357***	−4.0520***
2009–2013	−4.8578***	−4.7768***	−4.4908***	−4.3290***	−4.3069***	−4.3007***
2013–2017	−4.5797***	−4.4124***	−4.0721***	−3.9361***	−3.8855***	−3.8583***
2017–2022	−5.4187***	−5.0644***	−4.7547***	−4.6554***	−4.6452***	−4.5474***
R^2	0.8929	0.8993	0.9048	0.9003	0.9052	0.9076
Adjusted R^2	0.8798	0.887	0.8903	0.8881	0.8907	0.8904
AIC	198.0886	192.8997	192.157	192.0787	191.8466*	193.6698
BIC	219.966	214.7771	218.8959	213.9561*	218.5856	225.2704

Figure 1: Relationship between secondary schooling/ high school attainment ratio and infant mortality.



Equation VI shows that, when the ratio and secondary schooling for women and men are used together, equality prevails over the other education variables. While all retain their signs, only the ratio is significant at a 90% confidence level. The time fixed effects show that infant mortality decreases in each period, a desired outcome in any society.

Finally, Table 6 and Table 7 use life expectancy at birth (LE) at the end of each period as the dependent variable. GDP per capita has a quadratic effect on LE, meaning that regions with higher incomes at the beginning of each period tend to be regions with higher LE. The negative sign of the quadratic effect is a mystery to authors such as Barro and Lee [8], but we can infer that it is related to the epidemiological transition, where deaths are associated with diseases specific to the developed world such as diabetes, obesity, hypertension, etc.

We also identified a quadratic relationship between gender equality in education and life expectancy, suggesting that after a certain inflection point, higher levels of schooling ratios begin to increase life expectancy. For example, considering Model VII (two-way), the initial schooling ratio (ratioesci) has a coefficient of -34.49 (not significant), indicating that an increase in this ratio is associated with a decrease in life expectancy. However, the coefficient of its square (ratioesci2) is 21.27 (significant), suggesting a quadratic relationship where, after a certain inflection point, higher levels of schooling ratios begin to increase life expectancy. The inflection point is approximately 0.81.

Table 6: Dependent Variable: Life Expectancy, FE Model.

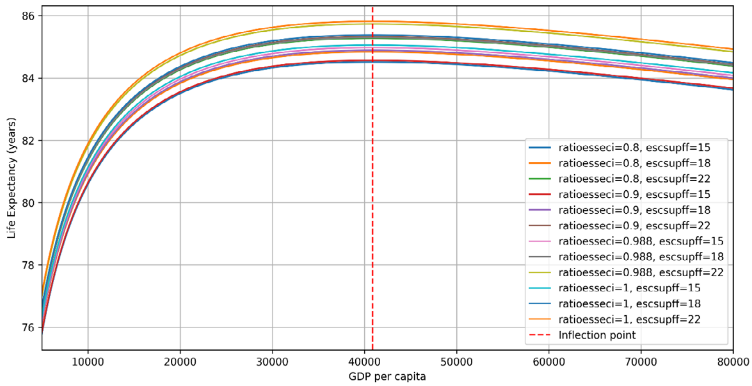
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
lnpibibi	42.2398***	37.7337***	41.5259***	40.9625***	44.5013***	47.1202**	30.6116
lnpibibi2	−1.8892**	−1.7712**	−1.9668**	−1.9597**	−2.1390**	−2.2775**	−1.4370
ratioesci	−32.7183	–	−34.7701	–	−34.9487	−34.8751	−34.4907
ratioeseci2	20.1048	–	20.7965*	–	20.6559*	20.4597*	21.2698*
escsuppromh	–	–	–	0.1753***	0.1622***	0.3007	0.0863
escsuppromf	–	0.1497**	0.1405**	–	–	−0.1355	−0.1641
escpromf	–	–	–	–	–	–	−0.2218
escpromh	–	–	–	–	–	–	2.3297
R^2	0.8428	0.85	0.863	0.8558	0.867	0.8682	0.8803
Adjusted R^2	0.8348	0.8444	0.8542	0.8504	0.8585	0.8579	0.8675
AIC	270.8391	264.8808	261.2463	261.5766	258.7703	260.0332	255.9558*
BIC	280.5624	272.1732	273.4004	268.869*	270.9244	274.6181	275.4023

Table 7: Estimation: Schooling and Life Expectancy, Two-Way Model.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
lnpibibi	12.6138***	12.4227***	13.2359***	14.2815***	14.8382***	13.1701***	13.2194***
lnpibibi2	−0.7475***	−0.7362***	−0.7759***	−0.8310***	−0.8581***	−0.7726***	−0.7803***
ratioeseci	−2.6261	–	−4.2210	–	−4.4485	−4.1955	−3.8592
ratioeseci2	2.0660	–	2.7189	–	2.7771	2.7097	2.6860
escsuppromh	–	–	–	0.0890***	0.0790***	−0.0029	−0.0276
escsuppromf	–	0.0987***	0.0912***	–	–	0.0936**	0.1165**
escpromf	–	–	–	–	–	–	−0.6274
escpromh	–	–	–	–	–	–	−0.5639*
1996–2003	5.2484***	5.0328***	4.9885***	5.0232***	4.9978***	4.9909***	5.0356***
2003–2009	6.7192***	6.2873***	6.2360***	6.2850***	6.2618***	6.2403***	6.3608***
2009–2013	7.7088***	7.0242***	6.9938***	7.0298***	7.0359***	7.0000***	7.1896***
2013–2017	8.6514***	7.6115***	7.6099***	7.6259***	7.6711***	7.6188***	7.8995***
2017–2022	9.2671***	7.7476***	7.7680***	7.8944***	7.9679***	7.7768***	8.1740***
R^2	0.9916	0.9926	0.9930	0.9923	0.9926	0.9930	0.9933
Adjusted R^2	0.9905	0.9918	0.9920	0.9914	0.9915	0.9919	0.9922
AIC	35.1964	22.1033	21.4836*	25.9211	26.4894	23.4879	24.0094
BIC	57.0737	41.5768*	45.7918	45.3677	50.7975	50.2179	55.8147

Additionally, Figure 2 shows the relationship between GDP per capita and life expectancy, considering different levels of ratios esseci and escsupff, as well as their quadratic effects. The curves have the shape of an inverted parabola, indicating that life expectancy increases with GDP per capita until reaching a turning point, after which further increases in GDP per capita contribute increasingly less to life expectancy and may even reduce it slightly. This behavior reflects the presence of diminishing returns in the relationship between income and health. The curves shift upward as ratios esseci increase, indicating that a higher ratios esseci are associated with longer life expectancy. The quadratic term ratioesseci2 has a negative coefficient, implying that there is a point beyond which further increases in ratioesseci have a diminishing effect on life expectancy.

Figure 2: Relationship Between GDP per Capita and Life Expectancy.



In summary, both GDP per capita and initial and female education levels significantly influence life expectancy, with nonlinear effects that reflect diminishing returns. Increases in ratioesseci and escsupff improve life expectancy, but the marginal benefits decrease at higher levels of these factors. The turning point for GDP per capita—approximately 40 million Chilean pesos (annually)—highlights the optimal level at which life expectancy is maximized. The results are robust and show that both female and male education are significant factors in improving national development. However, it is essential to emphasize that equity is also a relevant factor in explaining differences in life expectancy across Chilean regions.

To conclude, while empirical findings in the literature often point to a stronger impact of female education on growth not only due to increased human capital, but also because of better child nutrition, prenatal care, and knowledge of birth control, our empirical results emphasize that both female and male education are important for economic growth and development. Consistent with the findings of Hill and King [27,5], Knowles et al. [3], Tena et al. [28], Klasen [10], and Tansel and Güngör [29], among others, our results demonstrate that gender equality in education is a desirable goal for the Chilean economy and a driver of individual well-being across regions. Gender equality is especially important when evaluating indirect effects, as in most cases it proves to be more influential than the individual effect of male or female schooling.

5. Conclusions

Previous studies have shown that education is a key factor in understanding regional economic growth differences in Chile. They also demonstrate that educational disparities between women and men hinder growth through the accumulation of human capital—referred to here as the direct effect. This study provides robust evidence of the significant indirect effects of gender inequality in education on economic growth in Chile, mediated through life expectancy at birth, infant mortality, and the total fertility rate. The results show that greater gender equity in education not only improves these vital and demographic indicators, but also has a positive and significant impact on regional economic growth.

By analyzing three distinct models using vital and demographic variables as dependents (life expectancy, infant mortality, and total fertility rate), the study evidences the influence of education. Specifically, it highlights the importance of gender inequality in education, as this variable proves significant in most cases, even when controlling for both female and male education. It is concluded that gender disparity in secondary education (measured by the secondary schooling ratio) has a relevant impact in explaining regional disparities, outweighing other variables included in the models (though not necessarily reflected in the tables, such as average schooling ratio and higher education ratio).

While empirical findings in the literature emphasize the greater effect of women's education on growth—not only through increased human capital, but also due to better child nutrition, improved prenatal care, greater knowledge of birth control, etc.—our results underscore that both female and male education are important for greater economic growth and development. The study shows that gender equality in education is a desirable goal for the Chilean economy and a driver of individual well-being across all regions. This equality is particularly important when evaluating indirect effects, as in most cases it proved more influential than the individual effect of male or female education alone.

Public policies should focus on reducing gender gaps in education to foster more inclusive and sustainable economic development. It is crucial to implement educational programs that promote equal participation of women and men from an early age, as well as to ensure continuous access to higher education. It can be inferred that improving women's educational conditions not only impacts their own quality of life, but also affects future generations and society as a whole.

The study emphasizes the need for a gender perspective in the design of education and health policies, highlighting that investing in both female and male education yields significant returns in terms of economic and social well-being. Future studies will delve deeper into the evaluation of other mediating variables and consider the impact of educational policies on other aspects of social welfare.

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