UNIVERSIDADE CATÓLICA PORTUGUESA

Heterogeneity in the Long-Run Effect of Fertility on Economic Growth

José Pedro Ribeiro

Universidade Católica Portuguesa, Católica Porto Business School

2025

UNIVERSIDADE CATÓLICA PORTUGUESA

Heterogeneity in the Long-Run Effect of Fertility on Economic Growth

Master's Final Assignment in the modality of Dissertation
Presented to *Universidade Católica Portuguesa*
to obtain a Master's Degree in Business Economics

by

José Pedro Ribeiro

Under supervision of
Professor Ricardo Ribeiro

Universidade Católica Portuguesa, Católica Porto Business School
May 2025

Acknowlegements

Maximum 1 page (optiona

Resumo

Estudos empíricos geralmente descobriram que uma maior fertilidade tem um impacto negativo ou estatisticamente insignificante no crescimento económico. Apesar de os estudos que examinam o efeito de longo prazo serem escassos, eles têm demonstrado um efeito positivo consiste entre vários testes de robustez. Este estudo examine se estes efeitos são homogéneos. Os resultados sugerem que o efeito é heterogéneo entre países com taxas de fertilidade inicial diferentes tal como em países de geografias diferentes

Palavras-chave: fertilidade; crescimento económico; longo prazo; TFT; PIB per capita;

Abstract

Empirical studies generally found that higher fertility has either a negative or insignificant impact on economic growth. Although studies examining the long-term effects of fertility on growth are scarce, they have shown consistent positive effects across various robustness checks. This study examines whether these effects are homogeneous. The results suggest that the effect is heterogeneous across countries with different initial fertility rates as well as countries of different geographies

Keywords: fertility; economic growth; long-term; TFR; GDP per capita;

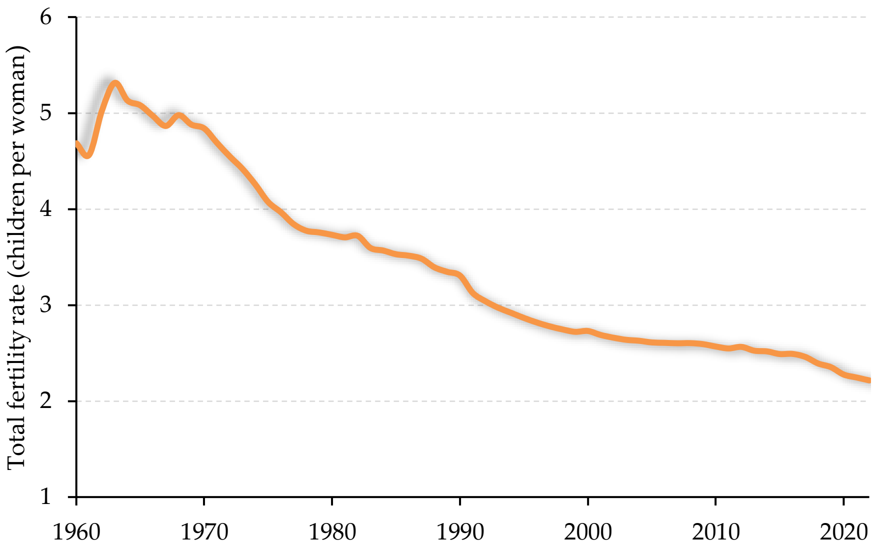
Contents

Table of Figures

Table of Tables

Chapter 1. Introduction

Over the last six decades, most countries around the world have experienced unprecedented declines in fertility rates (Figure 1) and increases in living standards. A widely accepted reason to justify this decrease could be the growing importance that parents are given on child quality (education, health, time spending) throughout time. As a result, the additional cost of having one more child tends to increase over time, leading couples to prefer having fewer children while investing more in each one (Becker & Lewis, 1973).



Note: The data is obtained from the Word Bank Development Indicators.
Figure 1: Fertility trend around the world

According to Bloom et al. (2010), when fertility rates fall below replacement level, the average age of the population tends to rise, and population growth slows down. However, the consequences go beyond demographics. There are also important economic effects. With fewer births, the number of workers financing pensions tends to decrease (Gertler, 1999), and overall productivity is affected, as individuals exhibit different levels of productivity depending on their age (Skirbekk, 2008). These various factors linked to the consequences of fertility decline have made the relationship between fertility and economic growth a relevant topic in academic research, raising the question of whether lower fertility hinders or promotes economic performance.

In general, from a theoretical perspective, fertility may have a nonlinear influence over economic growth. On the one hand, low fertility rates could allow a large share of resources to remain in the production sector rather than being diverted to childbearing. One another hand, higher fertility could boost growth if there are adequate mechanisms that allow to that growing population to int in labor market.

In order to examine this question from an empirical perspective, early studies, such as those by Kuznets (1967) and Kelley (1988), compared the fertility-growth relationship across countries. The results showed this relationship not to be, in fact, linear, but positive or negative depending on social, political, technological, institutional and economic factors of nations. However, these studies only focused on the short-term relationship and the cross-sectional results obtained were likely prone to endogeneity bias due to omitted factors. This could be caused by omitted variables — such as religion beliefs of countries, which can shape fertility preferences and influence attitudes toward work, education, and wealth creation — as well as from reverse causality, since economic growth can also impact fertility decisions.

To address this endogeneity bias, later studies adopted panel models. Those models tend to offer more accurate results compared to cross-sectional approaches (Islam, 1995) and helped mitigate, until certain degree, the exposure to causality (Berrington, 2006). Some of these studies found a negative (Barro, 2001, 2003) and statistically insignificant relationship between fertility and economic growth (De La Croix & Doepke, 2003). However, even when accounting for some of the endogeneity, these studies often still face challenges in providing consistent estimates.

As a result, subsequent research began using panel fixed effects model (Kelley & Schmidt, 1995) and combinations of instrumental variables and panel fixed effects model (Li et al., 2007). These approaches represented a methodological improvement over the panel data studies mentioned above by controlling for unobserved time-invariant and location-specific factors that could influence both fertility and economic growth. By accounting for these fixed factors, the risk of omitted variable bias is reduced. However, these models still primarily captured short-term effects of the fertility-growth relationship.

Huang (2024) was the first to successfully model both the short and the long-term effects, applying instrumental variables and fixed effect estimation techniques. To be able to capture both effects it's crucial that fertility is lagged, and the time span of the lagged years is not shorter than 20 years otherwise only the short-term is captured (Huang, 2024).

Theoretically, the short-term effect of fertility on growth is often negative, as more children increase dependency and reduce savings or investment per capita. In the long run, however, fertility can have a positive effect if it leads to a larger labor force and human capital accumulation, especially when accompanied by appropriate institutions and policies. This suggests that in the short run fertility reduces negatively economic growth but in the long run it may increase it, achieving a positive effect. This suggests also that the relationship between fertility and economic growth perhaps is not homogenous and that it can depend on factors like development level of countries. In order to examine this eventual heterogeneity, Huang (2024) grouped countries by the (initial) income level. He found same pattern, with high-income countries having a larger and longer positive effect compared with the medium and low-income countries

The aim of this thesis is to analyse both the short and long run effect of fertility in economic growth. The main contribution is to prove whether the consistent pattern identified by Huang (2024) holds across different country groupings.

Two extensions are proposed: one divides countries by fertility level (high and low) and another that divides countries by geography.

Its reasonable so assume that fertility may influence economic growth differently according with the extensions since countries don't follow the same pace in terms of demographic transition, the crucial sectors in their economies that absorb the labor force are different and social-cultural factors very distinctive.

Although this research replicates some aspects of Huang (2024) methodology, it still provides additional contributions to both the academic and management fields. From an academic perspective, it provides additional knowledge regarding the long-term effects of fertility on growth, an area still understudied, particularly with more updated data. Additionally, it considers two model extensions different from the ones applied by Huang (2024). From a management standpoint, the results may help policymakers by providing, in a more holistic way, what is the behavior of short and long run fertility on economic growth. With that knowledge policies could be designed according to the dynamic pattern of fertility in economic growth.

To examine this question, the thesis adopts a quantitative approach, utilizing secondary data from 137 countries spanning from 1960 to 2022, gathered from multiple data sources. The compiled panel data is used to regress the income growth rate on both current and lagged fertility. To address the potential endogeneity bias, the fixed effects technique is applied. The estimated coefficients for current and lagged fertility from the baseline are then used to calculate the accumulated effect of fertility in economic growth and the global decline in growth induced by the secular fertility decline.

The results from the baseline model are consistent with the ones from Huang (2024) showing a short-term negative effect of fertility on economic growth and a long-term positive effect of fertility on economic growth. However, the dynamic behavior of fertility on economic growth in the two extension models revealed heterogeneous patterns regarding the baseline, which is different from what Huang (2024) obtained. In low fertility countries, only the short-term negative effect is statistically significant. In high fertility countries, that only happens in the long run, with a positive effect. When applying the division by continents, Africa and Europe only exhibit a short-term negative effect. In Asia and Oceania, the delayed positive effect is observed and after a while a statistically significant negative. The Americas, in contrast, the effect in either, short or long-term, is not statistically significant.

This research is structured into five chapters, including this introduction. Chapter 2 presents the literature review, where the relevant theoretical frameworks necessary to understand the long-term effects of fertility on economic growth are discussed. Chapter 3 discusses the theoretical hypotheses as well as the equation and estimation method. Chapter 4 presents the empirical analysis, beginning with the identification and description of the data being used, followed by the baseline results and the two model extensions. Finally, Chapter 5 concludes the study, highlighting its limitations and offering recommendations for future research.

Chapter 2. Literature Review

To comprehend the theoretical effect of fertility on economic growth, this chapter discusses key theories that address the long-run effects of fertility and its role in shaping growth and productivity. It introduces six channels that explain how fertility might influence economic growth over time.

First, the classical economic growth theory (Malthus, 1798) offers a more pessimistic view of the fertility-growth relationship, as it suggests the absence of sustained growth (Hansen & Prescott, 2002). Although technological progress could temporarily overcome Malthusian stagnation by increasing both production and living standards of families, which could lead to higher fertility and lower mortality, Malthus argued that due to decreasing behavior of resources returns, like land, these economic gains would eventually diminish (Wrigley, 1988). This theory predicts a negative relationship between fertility and economic growth. As fertility rises, the economic gains are consumed by that growing population and returning the economy to a stagnation point.

Second, the neoclassical growth theory (Solow, 1956) addresses the stagnation paradigm by introducing the concept of steady-state growth, where countries can achieve sustained growth over time. The factors that positively influence this steady-state growth level include the accumulation of physical capital and saving rates, while population growth negatively impacts it (Mankiw et al., 1992). This is because available capital must be spread across the growing population of workers, which reduces capital productivity and, consequently, income per capita. Even though this theory explains the negative relationship between population growth and economic growth, it does not provide insight into how population growth itself is influenced, as it treats population growth as an exogenous factor (Mankiw et al., 1992).

Third, the theory of the quality and quantity tradeoff (Becker et al., 1990) helps fill that gap by considering that population growth is determined by families' decisions regarding whether to have more children or not. Another key difference compared with Solow (1956) and Malthus (1798) is that this theory incorporates human capital into its model and considers it the driver of economic growth. The existing level of human capital in an economy, which encompasses knowledge, skills, and education accumulated over time, determines both fertility rates and economic growth. In countries with high levels of human capital, there are more opportunities for individuals in terms of higher-paying jobs, advanced technologies, and better educational systems, which result in higher returns of investments made in acquiring qualifications (Becker et al., 1990). These higher returns can encourage families to have fewer children, as the costs of each child are higher, but at the same time leads economies to sustained growth. In contrast, countries with lower levels of human capital, there are fewer opportunities for education and skilled jobs, which tends to result in higher fertility rates as the returns of investing in human capital are lower leading them to a Malthusian stagnation.

Additionally, the theory introduces the concept of altruism within families (Becker & Barro, 1988). When parents are altruistic, they tend to prioritize the welfare of future generations. If parents anticipate higher long-term interest rates, a sign of future prosperity, they may choose to save and invest more. The prospect of higher future returns encourages them to sacrifice some current consumption, a substitution effect. This behavior could also lead parents to have more children, as they have an optimistic view on their children's future well-being. This investment could enhance the future consumption capacity of the next generations, even if they do not work as much. As a result, future demand, and consequently income per capita, could be stimulated, potentially surpassing the income levels of the parents.

Even if the model of quality and quantity trade-off (Becker et al., 1990) provides a solid explanation for the fertility and economic growth differences it has some limitations, especially two. First, although it mentions a Malthusian economy (stagnation), it does not consider the resource constraint as the cause of the stagnation. Instead, promotes the idea that is caused by the degree of human capital accumulation. Second, the model does not explain how the transition from stagnation to growth happens in countries.

This leads to the fourth theory, unified growth model, that tends to emphasize the interaction between demographic and economic forces. Historically, it was during the second phase of the Industrial Revolution the demographic transition started to be observed. According to Galor & Weil (1999), in the second phase of the Industrial Revolution acceleration of technological progress gradually increased the need for workers to be more qualified (like being able to read and write) which made parents appreciate more investment in human capital for their descendants. The acceleration of technological progress revealed then two effects over fertility rates (Galor & Weil, 2000). The first one was the improvements in the living standards of families, allowing them to invest more in the quality and quantity of their one child. As a result, initially the rise in household income led to an increase in the number of children parents chose to have. The second one occurred after the accumulation of human capital started to be noticed. The increase in technological progress has induced more resources for investments in human capital to the detriment of having more children due to the sense of providing for their offsprings better opportunities and quality of life. This idea supports the neoclassical growth theory that believes in technological progress to assure long term economic growth (Solow, 1956). But of course, other causes contributed to the demographic transitions. The decline of child labor promoted by education reforms (Galor et al., 2001) and child labor abolish laws (Doepke, 2004), the rise of life expectancy allowing an increase of the working time which makes the return of human capital higher and turns the option of having more children less attractive (Galor & Weil, 1999), and the decline of gender gap (Galor & Weil, 1996) also contributes for that. As women tend to earn more, the opportunity cost of having children increases (both in time and resources). Since the additional increase in wages doesn't fully compensate for the costs, many families may choose to have fewer children

While the unified growth theory provides a comprehensive framework to understand the transition from stagnation to sustained economic growth, it does not provide a good understanding of how the demographic changes may influence economic growth.

The fifth theory, demographic dividend theory, may have a contribution to that. Although the theory helps explain the demographic transition, like the unified growth theory, it primarily focuses on how changes in the age structure distribution can influence economic growth. The demographic dividend refers to a demographic opportunity that arises when the proportion of working-age individuals increases, and the dependency ratio (the proportion of dependent people) is low, in relation to the total population. However, this dividend can also occur if a decline in fertility leads to a decrease in the youth dependency ratio, even if the growth rate of the working-age population remains unchanged. This situation can still result in increased income per capita (Bloom & Williamson, 1998).

The demographic dividend depends on the changes of age structure and also on the following factors: labor supply, savings, and human capital. As more people enter the labor force, and if the labor market can absorb them, this can lead to an increase in income per capita. Furthermore, when people are employed, they tend to produce more, which leads to higher savings (Higgins & Williamson, 1997). These higher savings can be invested, stimulating further growth.

Regarding human capital, the demographic dividend is most effectively realized when there is early investment in education and healthcare policies that do not discriminate based on gender. Without such policies, a country may miss the opportunity to maximize growth and reduce poverty (Galor & Weil, 1996). If these policies are implemented properly, they can have a significant impact on economic growth, as seen in the Asian Miracle, where one-third of the of real per capita income growth between 1965 and 1990 was attributed to policies that capitalized on demographic changes (Bloom & Williamson, 1998). Hence, it is the combination of those factors that can ensure economic growth and not them separately.

Finally, sixth, Research and Development (R&D)-based growth models. Unlike the previous five models or theories, these models contradict the idea that fertility is harmful to economic growth. They argue that growth is driven by technological progress, which is endogenous, meaning it is explained by a country's capacity to engage in R&D, both in the public and private sectors. These models suggest that a higher population may increase the number of researchers, which in turn could lead to more innovations and knowledge through R&D efforts. This innovation could then be spread across firms and countries (spillovers), leading to increasing returns and enhance economic growth (Jones, 1995).

These six channels suggest that fertility, in the long run, can have either a positive or negative effect on economic growth. From a negative perspective, higher fertility increases consumption of economic gains to support a growing population, leaving the economy in a perpetual state of stagnation (Malthus, 1798). It also reduces parental investment per child, which lowers human capital accumulation, which is a key factor for sustainable growth (Becker et al., 1990). In the unified growth framework, high fertility may indicate that countries have not yet reached the stage of technological progress where investment in human capital becomes worthwhile and thus have not achieved sustained economic growth (Galor, 2005). Moreover, when capital investment does not keep pace with population growth, high fertility can lead to a decline in capital per worker and lower productivity (Solow, 1956).

On the positive side, a growing population can increase the number of potential innovators, enhancing productivity and technological progress (Jones, 1995). The impact of fertility can also be dynamic. Depending on demographic context, countries with high fertility could potentially benefit from a demographic dividend — a temporary window of accelerated growth due to a rising share of the working-age population (Bloom & Williamson, 1998).

Chapter 3. Theoretical Hypotheses and Method

3.1 Theoretical Hypotheses

Based on the literature review, some possible hypotheses are now proposed concerning the relationship between fertility and economic growth across different demographic and geographic contexts.

First, we expect the impact of fertility on economic growth to be heterogenous across countries with different initial fertility rates. In low-fertility countries, the short-term effect of fertility on economic growth is expected to be negative. In these countries, the return on human capital tends to be higher, which leads families to invest more per child and to reduce the number of children, prioritizing quality over quantity (Becker et al., 1990).

In high-fertility countries, the short-term effect may also be negative, especially because the cost of raising children overtime (Becker & Lewis, 1973) tends to be higher rather than the actual resources expended per child, since in these countries families tend to prioritize the number of children over their quality (Becker et al., 1990).

However, in the long run, these expected impacts are different. Because low-fertility countries already passed their demographic window they may not evidence positive impact but rather insignificant. In turn, in the higher-fertility countries, fertility can have a positive effect on economic growth since they can still benefit from an increase working age population in relation with dependent population (Bloom & Williamson, 1998).

Second, we expect the impact of fertility on economic growth to be heterogeneous across different geographies, as the stage of the demographic transition plays a key role in shaping how fertility affects growth. In Europe, where the demographic transition is largely completed, fertility is already low, and populations are aging. In such contexts, the negative short-term effect of fertility persists, as families continue to allocate more resources per child (Becker et al., 1990). Additionally, countries may experience the more profound consequences of sustained low fertility highlighted by Gertler (1999) and Skirbekk (2008). This could even intensify the negative effect if Governments increase public spending to reverse declining fertility rates. Regarding the further positive effect of fertility, the chance is that it does not exist since Europe fits in the category of low fertility countries that no longer have a demographic dividend.

A similar dynamic applies to North America, where the transition is also consolidated, and low fertility poses long-term challenges. In Latin America, most countries are in an advanced stage of the demographic transition, with significantly reduced mortality and declining fertility leading to the belief that the short-term effect is likely negative because of the quality prioritization effect (Becker et al., 1990). As a consequence, we do not expect these two sub-continents will show a long-term positive effect caused by the demographic dividend, as they fit in a more low-fertility countries context due its severe declines in the fertility rates.

In Asia & Oceania, the demographic landscape is steeper, and this variation could allow for both negative and positive effects of fertility to coexist. In countries like Japan, South Korea, and Australia, fertility is very low, and the population is aging, suggesting that the dynamic effects may resemble those of Europe, with predominantly negative effects. Conversely, in countries such as Afghanistan, Iran and Yemen, which are still undergoing the transition, higher fertility combined with a capacity of labor markets to absorb the growing population in working age may generate a positive effect of fertility throughout the demographic dividend mechanism

Lastly, in Africa, the demographic transition is at an early stage. Fertility remains high, while mortality has declined substantially, leading to rapid population growth. This demographic profile in African countries creates the possibility to benefit from long-term positive effects of fertility on growth. However, in the short-term, high fertility may have a negative impact, especially because in underdeveloped countries Government allocate resources from the production sector to respond to the needs of a growing population (Myint, 1958), rather than being driven primarily by the parent's expenditures. In these contexts, families tend to prioritize the number of children over their quality, which may reduce the per-child investment typically associated with negative fertility effects (Becker et al., 1990).

3.2 Method

In order to estimate the long-term dynamic effects of fertility while using the fixed effect estimation method, it is crucial that the model includes long-term lags of fertility, as follows:

$$y_{i,t} = \alpha_i + \delta_t + \sum_{h=0}^{H} \beta^h TFR_{i,t-h} + \lambda Z_{i,t} + \varepsilon_{i,t}, \qquad (1)$$

where $y_{i,t}$ is the annual growth rate of GDP per capita in country i in year t; α_i denotes the fixed effect associated to country i; δ_t denotes the fixed effect associated to country t, $TFR_{i.t-h}$ is the total fertility rate in country i lagged h years prior to the current year t, with h = 0, 1, 2, …H; $Z_{i,t}$ is the set of control variables and $\varepsilon_{i,t}$is the error term in country i in year t.

The use of $TFR_{i,t-h}$ instead of $TFR_{i,t}$ allows us to capture not only the short-term effect, but also the long-term effect of fertility on economic growth. In this context, β^0 is responsible to capture the short-term effect of fertility, while the remaining coefficients, which are the remaining coefficients, β_h for h > 0, capture the effect that follows the one from β^0, meaning the long-term effects. With all those coefficients its possible to compute the accumulated effect of fertility on economic growth as follow: $\prod_{0 \le h \le H}(1 + \beta^h) - 1$.

Equation (1) is associated with a collinearity problem that may result from the fact fertility rates in successive years are highly correlated with one another. If that issue is not addressed, the estimates of TFR could be imprecise and with the wrong sign (Huang, 2024).

So, instead of equation (1), we will follow Huang (2024) and transform it into a series of H+1 estimating equations, each equation only including one lagged term of TFR, with a lag length from 0 to H years:

$$y_{i,t} = \alpha_i^h + \delta_t^h + \beta^h TFR_{i,t-h} + \lambda^h Z_{i,t-h} + \varepsilon_{i,t}^h, \quad h = 0, 1, 2, \dots H. \qquad (2)$$

Having in equation (2) control variables lagged by the same number of years as TFR prevents future values of the controls from absorbing part of the true effect of lagged fertility (Huang, 2024).

Equation (2) adopts the local projections approach proposed by Jordà (2005), which is used to estimate how variables respond over time to a shock. This method is particularly useful for analyzing dynamic causal relationships (Stock

& Watson, 2018). However, a common concern with local projection models is the potential for serial correlation in the error terms (Ramey & Zubairy, 2018). Based on this, standard errors clustered at the country's level were chosen.

Equation (2), by using lagged panel data for both the independent variable and the control variables, can significantly reduce endogeneity bias arising from omitted variables and reverse causality. The use of a long length helps particularly in mitigating the second endogeneity source. Furthermore, the inclusion of countries and time fixed effects ensure that unobserved factors which vary only across countries or only over time do not bias the estimated effects of the explanatory variables on economic growth.

Chapter 4. Empirical Analysis

4.1 Data Description

Following Huang (2024), our analysis encompasses 137 countries (listed in Appendix 1). However, instead of focusing on GDP per capita and TFR data for each year from 1960 to 2016, it includes more recent years, extending the analysis to 2022. The dependent variable, GDP per capita growth rate, was obtained from the Maddison Project Database. The main independent variable, the total fertility rate, was collected from the World Bank. The vector of control variables includes life expectancy and infant mortality rate (both from the World Bank), years of schooling (from the Barro & Lee Database), and five-year lagged GDP per capita (from the Maddison Project Database). All these variables are described in Table 1.

Variable Name	Definition	Source
Growth rate of GDP per capita	Annual growth rate of real GDP per capita in 2011 USD	A
Total fertility rate	Average number of children a woman would have during all her reproductive life	B
Five-year lagged GDP per capita	Five-year lagged GDP per capita, in thousands of 2011 USD	A
Infant mortality rate	Number of infants dying before reaching one year of age, per 1000 births	B
Life expectancy	Number of years a newborn infant would live if at his birth the patterns of mortality would prevail throughout his life	B
Years of schooling	Years of total schooling for individuals aged 25 and over	C

Note: 1. Data sources A: The Maddison Project Database 2022; B: World Development Indicators, the World Bank; C: Barro & Lee (2015). 2. All data corresponds to the 137 countries over the period of 1960 and 2022. The growth rate of GDP per capita and fertility rates is calculated as five-year moving averages to minimize the confounding effects of short-term fluctuations Huang (2024)

Table 1: Data description

Table 2 presents the descriptive statistics of all variables:

Variables	Average	Median	Standard Deviation	Minimum	Maximum
GDP per capita growth rate	0.0191	0.0204	0.0341	-0.3977	0.2063
TFR	3.8044	3.2571	2.0038	0.8636	8.8472
Five-year lagged GDP per capita	9.687	5.540	10.774	378	81.725

Infant mortality rate	51.4275	37.3000	45.9886	1.9000	265,0000
Life expectancy	64.6779	67.3310	11.3243	11.9950	84.2110
Years of schooling	5.8271	5,5280	3.4513	0.0000	13.6380

Note: Statistics elaborated according with 6,318 observations
Source: Own elaboration
Table 2: Descriptive Statistics

The median country-year combination in the data has: (i) a GDP per capita growth rate of 2.04%; (ii) women that on average have 3.26 children; (iii) a five lagged year GDP per capita around 5.540 (in thousand USD); (iv) an infant mortality rate of 37.30; (v) a life expectancy of 67.33 years; (vi) individuals with 5.53 total years of schooling

4.2 Homogeneity (Baseline) Analysis

To analyze the dynamic effects of fertility on economic growth over time, we estimated equation (2). The time horizon of the estimated coefficients is the following: $h = 0,1, \dots 40$. This approach allows us to capture both the short-and long-run effect of fertility on GDP per capita growth rate across four decades.

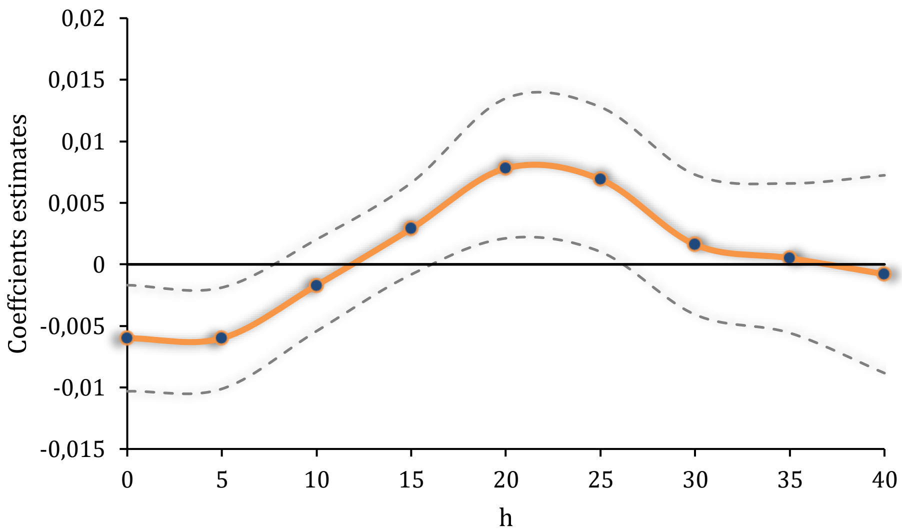
Figure 2 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), which regresses the annual growth rate of GDP per capita on the TFR lagged by different years. The confidence intervals are computed using standard errors clustered at the country level, as discussed in Chapter 3. The estimation is based on the full sample — annual data from 1960 to 2022 for 137 countries. Although the figure displays estimates at five-year intervals (e.g., 0, 5, ..., 40), the full set of yearly estimates from lag 0 to 40 is also available (listed in Appendix 2).

Figure 2 shows that higher fertility initially reduces the growth rate of GDP per capita and then increases it. The positive effect started to be statistically significant after the 16 lagged years, with its peak around 22 lagged years, and then gradually declines, becoming statistically insignificant after the 25th lagged year. Even though the exact timing of these turning points differs from Huang (2024), the overall pattern seems consistent — capturing both the short-run negative and long-run positive effects of fertility on growth. This supports the idea that earlier studies may have focused only on short-term impacts.

The initial statistical negative effect of higher fertility (from 0 until the 7th lagged year) could be explained by the neoclassical growth model. As population increases, resources that would otherwise be allocated to increase capital per worker tend ,instead, to be reallocated to support childbearing and their respective costs. This could lead to capital dilution, which in turn hinders economic growth (Solow, 1956). This reallocation could occur both at the household and government level.

Over time, the costs of childrearing decrease, and investment can be redirected toward the labor force, allowing for growth to increase. After 16th lagged year, the effect becomes positive and statistically significant, in line with Barlow (1994), which considers that fertility levels from 17 years ago could affect today's labor force. Additionally, a significant positive impact could also arise thanks to individuals that integrate innovative sectors that can contribute to technological progress that can enhance productivity, meaning possible increases in the GDP per capita growth rate.

The fact that the peak of the positive effect is observed at the 22nd lagged year followed by a gradual decline of the effect of fertility rates in economic growth may be because it si during that age that reproductive age tends to be located (Huang, 2024).



Note: Current and lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on the data of 137 countries over 1960- 2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.
Source: Own elaboration
Figure 2: Baseline Estimates

The accumulated effect, computed following Huang (2024) is, of 4.19% which means that an increase of one-unit in the TFR would raise the GDP per capita by 4.19% for an average sample country over 4 decades.[1] Between 1960 and 2022, the TFR has declined by 2.9021 p.p for the average sample country, which implies that long run fertility declined the global GDP per capita by 7.8450% (4.1900 *2.9021*40/62) over 4 decades.[2]

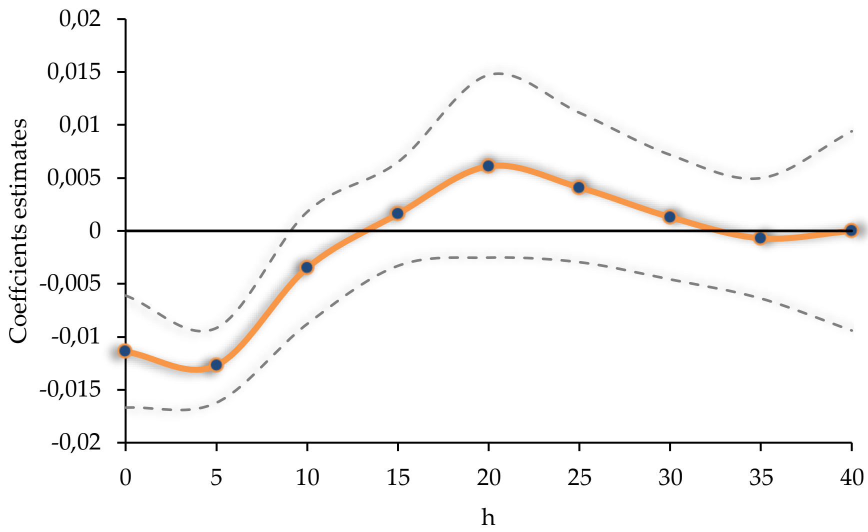
[1] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of 1.8274%.
[2] The value 62 corresponds to the total of years that this thesis analysis.

4.3 Heterogeneity Analysis: Fertility

We now examine whether the impact of fertility on economic growth is heterogenous across countries with different initial fertility levels. To do so, we divided the sample between high and low fertility countries. This is crucial to understand how the demographic stages of countries may influence the fertility-growth interactions. The criteria used to do that separation consisted in computing the median TFR in 1960, the first year of the study, which was 6.1822. Using that value as reference, all the countries with TFR lower or equal to 6.1822 were considered low fertility countries and those with a TFR higher were considered high fertility countries. Based on this criterion, 69 countries were classified as low-fertility and 68 as high-fertility (listed in Appendix 3).

4.3.1 Low Fertility Countries

Figure 3 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), using solely low fertility countries. It shows that higher fertility initially reduces the growth rate of GDP per capita and then increases it. After the 9th lagged year, the effect becomes statistically insignificant. This dynamic pattern may arise from the fact that most of these countries tend to fit in the category of countries where the human capital is the engine or is becoming the engine of the economic growth rather than capital accumulation (Galor & Moav, 2004). In these contexts, countries tend to have a high return on investments in human capital (Becker et al., 1990), making it worthwhile for parents to prioritize quality over quantity of children. As child mortality is also low, the likelihood of children surviving into adulthood is also high, reinforcing the incentive to invest more in their education and well-being (Strulik, 2004). Which could justify the initial negative effect of fertility on growth.



Note: Current and lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on the data of low-fertility countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.
Source: Own elaboration
Figure 3: Low-Fertility Countries Estimates

Then the effect becomes statistically insignificant until the end, likely because these countries have already passed the demographic window of opportunity (Bloom & Williamson, 1998). Their long run growth seems no longer be driven by increases in the labor force through fertility but instead could be driven by individual productivity gains through human capital accumulation (Strulik et al., 2013).

The accumulated effect in those countries over four decades is estimated at -5.4265%.[3]

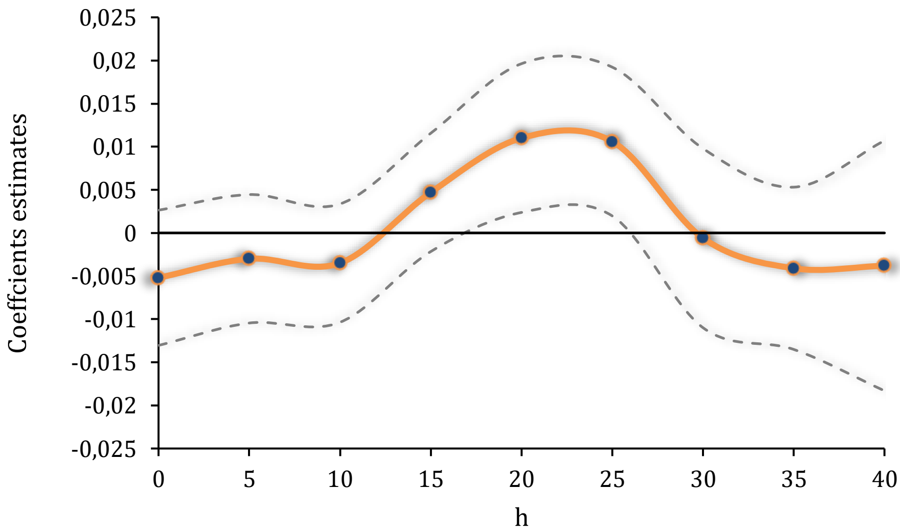
4.3.2 High Fertility Countries

Figure 4 shows that the initial effect of fertility on GDP per capita growth rate is statistically insignificant and endures until 17th lagged year. After that it

[3] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of -10.4469%.

becomes positive with its peak at the 23rd lagged year after which they enter a decline and becomes again statistically insignificant after the 25th lagged year.

The fact that the initial negative effect of fertility on growth rate is statistically insignificant could be explained by the relatively low cost of raising children in these countries compared with low-fertility countries. The socioeconomic context of the high-fertility countries seems to align with the theory of Becker et al. (1990), which suggests that these countries may tend to have a rate of return on human capital lower than the perceived return on having more children, so families would prioritize quantity over quality. As a result, investment per child is reduced, potentially attenuating the real initial negative impact of fertility on growth, turning it statistically insignificant.



Note: Current and lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on the data of high-fertility countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors

Figure 4: High-Fertility Countries Estimates

Because these countries still have an ongoing demographic transition, it could be reasonable to interpret the positive effect of fertility rates on economic growth in high-fertility countries driven by the demographic dividend, similarly to what occurred during the Asian Miracle where the size of the labor force entering the market could be (Bloom & Williamson, 1998) more decisive than their qualifications or skills. The peak of this positive effect is observed at the 23rd lagged year and then gradually declines, which may coincide with the reproductive age of those cohorts (Huang, 2024).

The accumulated effect in those countries over four decades is estimated to be 5,1415%.[4]

4.4 Heterogeneity Analysis: Geography

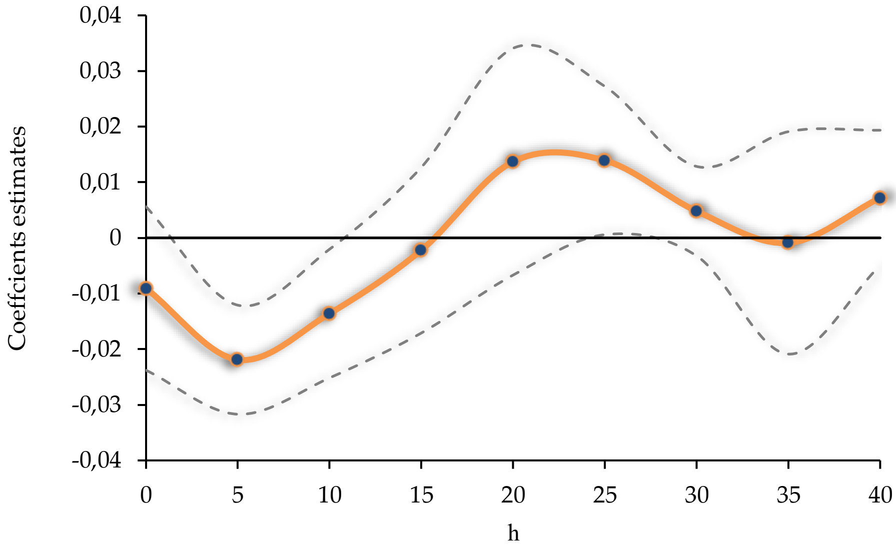
We now examine whether the impact of fertility on economic growth is heterogenous across geographies. To do so four regions are established: Europe, America, Africa, and Asia & Oceania (combined). By applying this classification, the goal is to examine whether the behavior of the relationship between fertility and economic growth follows a constant pattern across geographies or not.

4.4.1 European Countries

Figure 5 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), using solely European countries. It shows that the initial effect of fertility rates first reduces and then increases growth. The negative impact is statistically significant from the 1st lagged year until the 10th lagged year. After that it became statistically insignificant until the last lagged year.

[4] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of 9.4048%.

The initial negative impact of fertility on economic growth in Europe may reflect the continent already consolidated the demographic context, characterized by both low fertility and mortality rates. Given this scenario, and the fact that European countries typically exhibit higher returns to skills and education (human capital) parents may prefer to invest in the quality of children rather than quantity (Becker et al., 1990), which raises the cost of childrearing. In addition, Governments have implemented family policies aimed at adapting to these new demographic and economic realities (Gauthier, 2002), which may further reinforce the initial negative effect, because those measures could deviate resources from the production activities, which may impact negatively capital accumulation and productivity (Solow, 1956).



Note: Current and lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on the data of 29 countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.
Figure 5: European Countries Estimates

Although a positive effect is later observed, it is not statistically significant. This could be because these countries have already completed their demographic transition and thus no longer benefit from the demographic dividend. The size of the labor force alone appears to have little impact on growth, with productivity increasingly tied to individual skills and qualifications, that is, to human capital (Galor, 2005). Another possible explanation is the labor market's limited capacity to absorb new entrants, especially the youth. In several European countries, youth unemployment remains high (Lutz & Skirbekk, 2005) which may help explain why a significant positive impact is not observed.

The accumulated effect in Europe, over four decades, is estimated to be -4,8338%.[5]

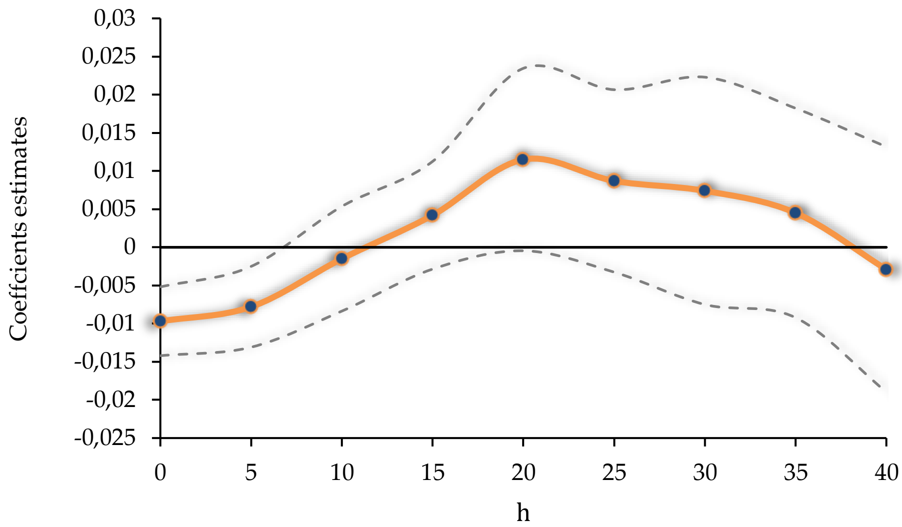
4.4.2 African Countries

Figure 6 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), using solely African countries. It reveals that initially fertility (from lagged year 0 to 6) rates have a negative and statistically significant impact on growth, but progressively that impact is reduced. After the 6th lagged year, the impact becomes statistically insignificant for the rest of the lags.

As Africa is still the continent in the earlier stages of demographic transition, characterized by very high fertility rates, relatively of world standards, despite the massive decrease in mortality due to medical improvements associated with public health practices (Bloom et al., 1998), it's reasonable to assume that they could fit in the country category of Becker et al. (1990) where families prioritize quantity rather than quality making the cost per child relatively lower. So, the initial negative effect could also be an answer of social and economic organizations in those underdeveloped countries. Instead of using their inputs to

[5] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of -16.7071%.

produce goods that can be exported they shift to providing means of helping the increasing population (Myint, 1958).



Note: Current lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on 47 countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.

Figure 6*:* African Countries Estimates

Although the positive effect of fertility on economic growth is not statistically significant, the demographic context of Africa leaves space for a potential demographic dividend. The reasons for that potential not being realized could be because of the economic structures in African countries. A large proportion of the labor force continues to be absorbed into low-productivity sectors, such as small-scale farming and services, while the number of formal sector jobs in more productive areas, such as manufacturing, is not growing rapidly enough to accommodate the increasing labor supply (Cleland & Machiyama, 2017). This means that despite having a growing labor force, the insufficient labor demand in high-productivity sectors may contribute to the statistically insignificant positive effect of fertility on economic growth.

The accumulated effect in Africa, over four decades, is estimated at 11,9223%.[6]

4.4.3 American Countries

Figure 7 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), using solely American countries. It indicates that higher fertility initially reduces and later increases the economic growth rate. The positive impact is shown after the 21st lagged year, reaching its respective peak at the 31st lagged year, followed by a continuous decline. However, across all the lags, the effect is statistically insignificant.

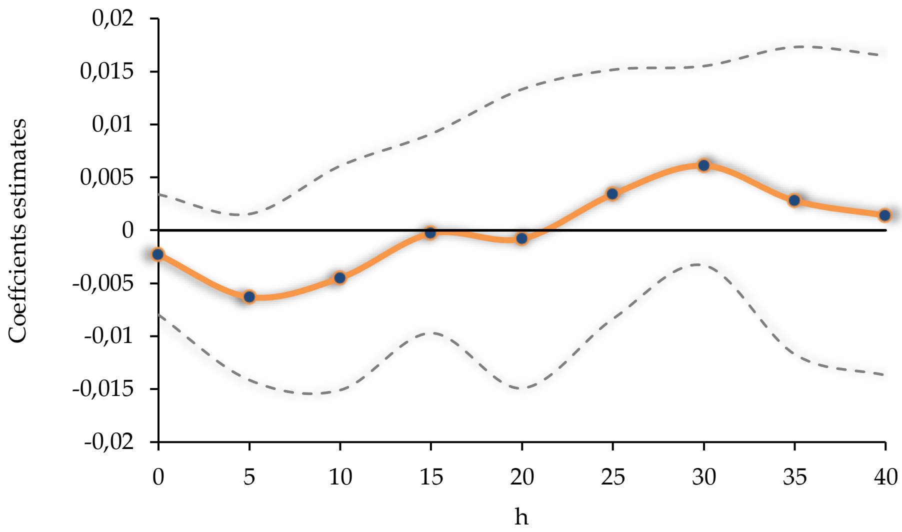
The reason for that results could be associated to the deep heterogeneity across the countries in the American continent. In Latin America, despite episodes of economic expansion since the 1990s, labor market deterioration (marked by rising unemployment and a surge in informal employment) has weakened the capacity to absorb the growing workforce productively, thereby limiting the realization of a demographic dividend. Moreover, regional differences in production specialization may have contributed to this pattern. While the Northern and Central parts of Latin America are more oriented towards manufacturing and service sectors that tend to generate formal employment, the Southern region is largely specialized in natural-resource-intensive goods, which are more associated with informal or low-quality jobs (Ocampo, 2004).

Weak governance and protectionist policies (Bloom et al., 2003) may also have limited foreign investment and economic diversification, further constraining job creation. Additionally, cultural factors, such as traditionally low female labor force participation in predominantly Roman Catholic Latin American countries,

[6] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of -5.7816%.

have resulted in underutilization of the potential workforce (Psacharopoulos & Tzannatos, 1989).

Together, these structural issues could explain why the demographic dividend has not materialized, especially when compared to North America, where more open governance, particularly regarding immigration, allowed a clearer demographic dividend effect (Bloom et al., 2003).



Note 7: Current lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on 27 countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.

Figure 7: American Countries Estimates

Together, these structural issues could explain why the demographic dividend has not materialized, especially when compared to North America, where more open governance, particularly regarding immigration, allowed a clearer demographic dividend effect (Bloom et al., 2003).

The accumulated effect in America, over four decades, is estimated to be -0,0037%.[7]

4.4.4 Asian & Oceanian Countries

Figure 8 presents the estimates of β^h and the respective 95% confidence intervals obtained from equation (2), using solely Asian & Oceanian countries. It indicates that, initially, fertility rates reduce economic growth but then increase it. The initial effect is not significant. However, after the 16th lagged year, the effect becomes positive and statistically significant, peaking at the 21st lagged year. After the peak, the effect declines and after the 23rd lagged year becomes statistically insignificant. In the final four lagged years, fertility once again shows a negative effect on growth rate, which, this time, is statistically significant.

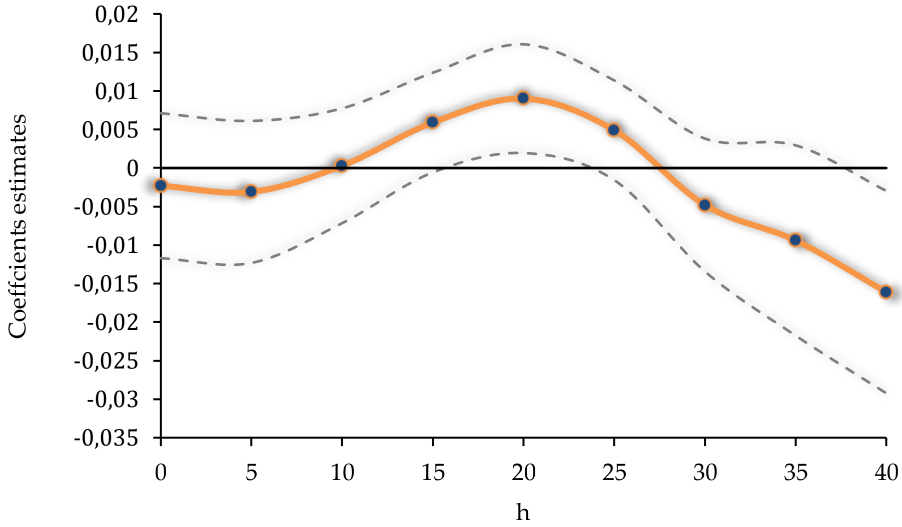
The initial negative effect of higher fertility, which is statistically insignificant, could be explained by three factors. First, the labor market in Asia tends to be inflexible, viewing women primarily as workers rather than recognizing also their role as mothers, which limits their time and support for family responsibilities. Second, pronatalist policies have been difficult to implement effectively due to bureaucratic resistance. Third, patriarchal family structures place the burden of childrearing mostly on women, increasing the personal cost of motherhood (Frejka et al., 2010).

These cultural, social and political factors, particularly in more developed Asian countries, may influence the overall cost of children, both in time and resources, by possibly attenuating the real impact of fertility on economic growth to a point where the short-term effect becomes statistically insignificant.

[7] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of 0%.

The prolonged positive effect observed from 17 to 23 lagged years may reflect the demographic dividend, as Asian countries underwent demographic transitions at different paces. East Asia, for instance, reached a more advanced stage characterized by low fertility and mortality rates, followed by Southeast and South-Central Asia, where the transition is still ongoing. In contrast, the Middle East continues to exhibit relatively high fertility rates compared to global standards (Bloom et al., 2003). This demographic configuration possibly allowed many Asian countries to benefit from a growing labor force that could be absorbed into both agricultural and industrial sectors, which might explain why the positive effect is clearly observed in this continent. Another reason that could reinforce the positive influence in growth is the significant integration of women into the labor market is some regions, like in East and Pacific Asia (Bloom & Freeman, 1986). The peak at the 21st lagged year, and the gradual decline, could represent the age at which individuals may begin their reproductive life and posterior to that a new cycle happens again (Huang, 2024).

An interesting pattern is that in the last lagged years (37 to 40), fertility appears to have a negative significant effect on economic growth. This could be linked to the aging of the labor force. As workers get older, it may becomes harder for them to adapt to structural changes in the economy (Clark et al., 1978) unlike younger workers who tend to adjust more easily.



Note 8: Current lagged effect of TFR on the annual growth rate of GDP per capita. The estimated coefficients of TFR are associated with model (2), based on 34 countries over the 1960-2022 period. Each dot on the solid line is an estimate of the TFR coefficient and the years in the x-axis correspond to that specific lag. The dashed lines are the lines defining the 95% confidence intervals, calculated using country-clustered standard errors.

Figure 8: Asian & Oceanian Countries Estimates

This slower adaptation may contribute to structural unemployment, which can drag down economic growth. The explanation becomes even more plausible when considering that some Asian countries had not yet completed their transition to fully industrialized economies. To achieve that transition, one of the conditions is a higher level of education (Oshima, 1983). However, older generations might lack the flexibility and human capital required for such transformation (Clark et al., 1978), which could explain the negative impact observed at these later lags.

The accumulated effect in Asia & Oceania, over four decades, is estimated to be -4,3609%.[8]

[8] The accumulated effect was also computed by considering the estimated coefficients that were not statistically significant as zero. This resulted in an accumulated effect of -0.0314%.

Chapter 5. Conclusion

This thesis examined the effect of fertility on economic growth. The estimates under the homogenous case suggest significant (i) negative short-term lagged effects of higher fertility rates on economic growth, probably driven by the costs of raising children; and (ii) positive long-term lagged positive effects which may be induced by the entry of those children into the labor forcing, helping boosting growth.

We then consider the heterogenous case. The results from the first extension were not consistent with the pattern observed in the baseline. While low-fertility countries exhibited only the negative effect of fertility — and not the positive one — in a statistically significant way, high-fertility countries captured only the positive effect, with the negative effect being statistically insignificant.

Regarding the second extension, which focused on analyzing the effect of fertility on economic growth across geographies, the results also deviated from the ones obtained in the baseline. In both Europe and Africa, only the short-term lagged effect of fertility was statistically significant. In Asia & Oceania, only the long-term positive impact was captured, along with a new pattern not observed in the baseline — a negative effect of fertility in the last four lagged years. Finally, in the Americas, the estimated effects were consistently statistically insignificant throughout all lagged years.

This heterogeneity in the results could be attributed to several reasons: the pace of the demographic transition in the different countries and continents; the relative importance of human capital in driving economic growth; the kind of sectors that absorb the growing labor force; cultural, social and political characteristics; and the capacity of labor supply to attend to the specific demanded needs of the labor market.

All these findings could provide insights for Governments. For instance, while Governments may aim to industrialize their economies and mechanize sectors to enhance productivity, institutions should also focus on the labor supply side — that is, the workforce — and not just on stimulating demand. This implies promoting educational initiatives, both formal (through schools and universities) and informal (such as learning by doing), that respond to the evolving demands of transforming sectors. By moving away from standardized programs that have been applied across generations, structural unemployment that might otherwise emerge could potentially be avoided or at least mitigated.

Just like any other study this one is not free from limitations. According to (Huang, 2024) even with FE method some endogeneity bias remains and to deal better with that an approach using an instrumental variables (IV) approach can help. This study did not use the IV approach only the FE approach. So, it would be fascinating to see an analysis, like this, on the impact of fertility on economic growth with these two approaches together. Another suggestion for further research is to separate the analysis of American continent to see if separately in North America and Latin America the positive effect of lagged fertility on economic growth could still be captured.

Declaration of generative AI And AI-assisted technologies in the writing process

During the preparation of my written thesis, "Heterogeneity in the long-run effect of fertility on economic growth", ChatGPT from OpenAI and Chatpdf were used for the following tasks: helping understanding the literature review theory, data description regarding graphs, coding assistance in statistics platform, better understanding of articles contend, bring fluidity and grammatical correction to the writing process, with the prompts used listed at the end of the document in the Prompts List section. After using this tools services, I reviewed and edited the content as necessary, and I take the full responsibility for the content of the work presented.

I also declare that I am aware of and respect the Artificial Intelligence Rules of Conduct of Católica Porto Business School.

Bibliography

Barlow, R. (1994). Population Growth and Economic Growth: Some More Correlations. In *Source: Population and Development Review* (Vol. 20, Issue 1). https://www.jstor.org/stable/2137634

Barro, R. J. (2001). *Human Capital and Growth* (Vol. 91, Issue 2). American Economic Association.

Barro, R. J. (2003). Determinants of Economic Growth in a Panel of Countries. *Annals of Economics and Finance* (Vol. 4).

Becker, G. S., & Barro, R. J. (1988). A Reformulation of the Economic Theory of Fertility. *The Quarterly Journal of Economics* (Vol. 103, Issue 1).

Becker, G. S., & Lewis, H. G. (n.d.). *On the Interaction between the Quantity and Quality of Children*. https://about.jstor.org/terms

Becker, G. S., Murphy, K. M., & Tamura, R. (1990a). Human Capital, Fertility, and Economic Growth. In *Source: Journal of Political Economy* (Vol. 98, Issue 5). https://about.jstor.org/terms

Becker, G. S., Murphy, K. M., & Tamura, R. (1990b). Human Capital, Fertility, and Economic Growth. In *Source: Journal of Political Economy* (Vol. 98, Issue 5). https://about.jstor.org/terms

Becker, G. S., Murphy, K. M., & Tamura, R. (1990c). Human Capital, Fertility, and Economic Growth. In *Source: Journal of Political Economy* (Vol. 98, Issue 5). https://about.jstor.org/terms

Becker, G. S., Murphy, K. M., & Tamura, R. (1990d). Human Capital, Fertility, and Economic Growth. In *Source: Journal of Political Economy* (Vol. 98, Issue 5). https://about.jstor.org/terms

Becker, G. S., Murphy, K. M., & Tamura, R. (1990e). Human Capital, Fertility, and Economic Growth. In *Source: Journal of Political Economy* (Vol. 98, Issue 5). https://about.jstor.org/terms

Berrington, A. (2006). *An Overview of Methods for the Analysis of Panel Data 1 ESRC National Centre for Research Methods NCRM Methods Review Papers NCRM/007*.

Bloom, D. E., Canning, D., & Finlay, J. E. (n.d.). *2 Population Aging and Economic Growth in Asia*.

Bloom, D. E., Canning, D., & Sevilla, J. (n.d.). *Chapter Title: DEMOGRAPHIC TRANSITIONS AND THE "DEMOGRAPHIC DIVIDEND" Book Title: The Demographic Dividend Book Subtitle: A New Perspective on the Economic Consequences of Population Change*. https://doi.org/10.7249/mr1274wfhf-dlpf-rf-unpf.10

Bloom, D. E., & Freeman, R. B. (1986). The Effects of Rapid Population Growth on Labor Supply and Employment in Developing. In *Development Review* (Vol. 12, Issue 3). https://about.jstor.org/terms

Bloom, D. E., Sachs, J. D., Collier, P., & Udry, C. (1998). Geography, Demography, and Economic Growth in Africa. In *Source: Brookings Papers on Economic Activity* (Vol. 1998, Issue 2).

Bloom, D. E., & Williamson, J. G. (1998a). Demographic Transitions and Economic Miracles in Emerging Asia. In *Source: The World Bank Economic Review* (Vol. 12, Issue 3). https://about.jstor.org/terms

Bloom, D. E., & Williamson, J. G. (1998b). Demographic Transitions and Economic Miracles in Emerging Asia. In *Source: The World Bank Economic Review* (Vol. 12, Issue 3). https://about.jstor.org/terms

Clark, R., Kreps, J., & Spengler, J. (1978). Economics of Aging: A Survey. In *Source: Journal of Economic Literature* (Vol. 16, Issue 3).

Cleland, J., & Machiyama, K. (2017). *The Challenges Posed by Demographic Change in sub-Saharan Africa: A Concise Overview* (Vol. 43). https://about.jstor.org/terms

De La Croix, D., & Doepke, M. (2003). *Inequality and Growth: Why Differential Fertility Matters* (Vol. 93, Issue 4).

Doepke, M. (2004). Accounting for Fertility Decline during the Transition to Growth. In *Source: Journal of Economic Growth* (Vol. 9, Issue 3).

Frejka, T., Jones, G. W., & Sardon, J.-P. (2010). *East Asian Childbearing Patterns and Policy Developments* (Vol. 36, Issue 3). https://about.jstor.org/terms

Galor, O. (n.d.). The Demographic Transition and the Emergence of Sustained Economic Growth. In *Source: Journal of the European Economic Association* (Vol. 3, Issue 3). https://www.jstor.org/stable/40004992

Galor, O., & Moav, O. (2004). *From Physical to Human Capital Accumulation: Inequality and the Process of Development*. *71*(4). https://about.jstor.org/terms

Galor, O., Moav, O., Acemoglu, D., Angrist, J., Akerlof, G., Caballe, J., Glaeser, E., Goldin, C., Grossman, H., Katz, L., Lavy, V., Mayshar, J., Mokyr, J., Paserman, D., Robinson, J., & Weil, D. (2001). Das Human Kapital: A Theory of the Demise of the Class Structure. In *Economic Growth*.

Galor, O., & Weil, D. N. (1996). *The Gender Gap, Fertility, and Growth* (Vol. 86, Issue 3).

Galor, O., & Weil, D. N. (1999). *From Malthusian Stagnation to Modern Growth* (Vol. 89, Issue 2). American Economic Association.

Galor, O., & Weil, D. N. (2000). *Population, Technology, and Growth: From Malthusian Stagnation to the Demographic Transition and beyond* (Vol. 90, Issue 4).

Gauthier, A. H. (2002). *Family Policies in Industrialized Countries: Is There Convergence?* (Vol. 57, Issue 3).

Gertler, M. (1999). Government debt and social security in a life-cycle economy*. In *Conference Series on Public Policy* (Vol. 50). www.elsevier.nl/locate/econbase

Hansen, G. D., & Prescott, E. C. (2002). *Malthus to Solow* (Vol. 92, Issue 4).

Higgins, M., & Williamson, J. G. (1997). Age Structure Dynamics in Asia and Dependence on Foreign Capital. In *Development Review* (Vol. 23, Issue 2).

Huang, K. (2024a). Fertility and long-term economic growth. *Economic Inquiry*, *62*(3), 1152–1171. https://doi.org/10.1111/ecin.13216

Huang, K. (2024b). Fertility and long-term economic growth. *Economic Inquiry*, *62*(3), 1152–1171. https://doi.org/10.1111/ecin.13216

Huang, K. (2024c). Fertility and long-term economic growth. *Economic Inquiry*. https://doi.org/10.1111/ecin.13216

Islam, N. (1995). Growth Empirics: A Panel Data Approach. In *Source: The Quarterly Journal of Economics* (Vol. 110, Issue 4). https://about.jstor.org/terms

Jones, C. I. (1995a). R & D-Based Models of Economic Growth. In *Source: Journal of Political Economy* (Vol. 103, Issue 4). https://www.jstor.org/stable/2138581

Jones, C. I. (1995b). R & D-Based Models of Economic Growth. In *Source: Journal of Political Economy* (Vol. 103, Issue 4). https://www.jstor.org/stable/2138581

Jordà, Ò. (2005). *Estimation and Inference of Impulse Responses by Local Projections* (Vol. 95, Issue 1).

Kelley, A. C. (1988). Economic Consequences of Population Change in the Third World. In *Source: Journal of Economic Literature* (Vol. 26, Issue 4).

Kelley, A. C., & Schmidt, R. M. (1995). Aggregate Population and Economic Growth Correlations: The Role of the Components of Demographic Change. In *Source: Demography* (Vol. 32, Issue 4).

Kuznets, S. (1967). *Population and Economic Growth* (Vol. 111, Issue 3).

Li, H., Zhang, J., & Zhang, J. (2007). Effects of longevity and dependency rates on saving and growth: Evidence from a panel of cross countries. *Journal of*

Development Economics, *84*(1), 138–154. https://doi.org/10.1016/j.jdeveco.2006.10.002

Mankiw, N. G., Romer, D., & Weil, D. N. (1992). A Contribution to the Empirics of Economic Growth. In *Source: The Quarterly Journal of Economics* (Vol. 107, Issue 2). https://www.jstor.org/stable/2118477

Myint, H. (1958). The "Classical Theory" of International Trade and the Underdeveloped Countries. In *Source: The Economic Journal* (Vol. 68, Issue 270).

Ocampo, J. A. (2004). Latin America's Growth and Equity Frustrations during Structural Reforms. In *Source: The Journal of Economic Perspectives* (Vol. 18, Issue 2).

Oshima, H. T. (1986). The Transition from an Agricultural to an Industrial Economy in East Asia. In *Source: Economic Development and Cultural Change* (Vol. 34, Issue 4). https://about.jstor.org/terms

Psacharopoulos, G., & Tzannatos, Z. (1989). Female Labor Force Participation: An International Perspective. In *Source* (Vol. 4, Issue 2). https://www.jstor.org/stable/3986509

Ramey, V. A., & Zubairy, S. (2018). Government Spending Multipliers in Good Times and in Bad. *Source: Journal of Political Economy*, *126*(2), 850–901. https://doi.org/10.2307/26550391

Skirbekk, V. (2008). Age and Productivity Potential: A New Approach Based on Ability Levels and Industry-Wide Task Demand. In *Population Aging, Human Capital Accumulation, and Productivity Growth* (Vol. 34). https://www.jstor.org/stable/25434764

Solow, R. M. (1956a). A Contribution to the Theory of Economic Growth. In *Source: The Quarterly Journal of Economics* (Vol. 70, Issue 1).

Solow, R. M. (1956b). A Contribution to the Theory of Economic Growth. In *Source: The Quarterly Journal of Economics* (Vol. 70, Issue 1).

Solow, R. M. (1956c). A Contribution to the Theory of Economic Growth. In *Source: The Quarterly Journal of Economics* (Vol. 70, Issue 1).

Stock, J. H., & Watson, M. W. (2018). Identification and Estimation of Dynamic Causal Effects in Macroeconomics using External Instruments. *The Economic Journal* (Vol. 128, Issue 610).

Strulik, H. (2004). Economic growth and stagnation with endogenous health and fertility. *Journal of Population Economics*, *17*(3), 433–453. https://doi.org/10.1007/s00148-004-0188-z

Strulik, H., Prettner, K., & Prskawetz, A. (2013). The past and future of knowledge-based growth. *Source: Journal of Economic Growth*, *18*(4), 411–437. https://doi.org/10.1007/s

Thomas Malthus An Essay on the Principle of Population 1798 AN ESSAY ON THE PRINCIPLE OF POPULATION, AS IT AFFECTS THE FUTURE IMPROVEMENT OF SOCIETY WITH REMARKS ON THE SPECULATIONS OF MR. (n.d.-a).

Thomas Malthus An Essay on the Principle of Population 1798 AN ESSAY ON THE PRINCIPLE OF POPULATION, AS IT AFFECTS THE FUTURE IMPROVEMENT OF SOCIETY WITH REMARKS ON THE SPECULATIONS OF MR. (n.d.-b).

Wrigley, E. A. (1988). Supplement: Population and Resources in Western Intellectual Traditions. In *Development Review* (Vol. 14). https://about.jstor.org/terms

Appendix

Appendix 1: Sample Countries

Afghanistan	Dominican Republic	Lebanon	Puerto Rico
Albania	Ecuador	Lesotho	Romania
Argentina	Egypt, Arab Rep.	Liberia	Russian Federation
Australia	El Salvador	Lybia	Rwanda
Austria	Equatorial Guinea	Macedonia	Sao Tome and Principe
Bangladesh	Ethiopia	Madagascar	Saudi Arabia
Barbados	Finland	Malawi	Senegal
Belgium	France	Malaysia	Sierra Leone
Benin	Gabon	Mali	Singapore
Bolivia	Gambia	Malta	Slovenia
Bosnia	Germany	Mauritania	South Africa
Botswana	Ghana	Mauritius	Spain
Brazil	Greece	Mexico	Sri. Lanka
Bulgaria	Guatemala	Mongolia	St. Lucia
Burkina Faso	Guinea	Montenegro	Sudan
Burundi	Guinea-Bissau	Morocco	Swaziland
Cabo Verde	Haiti	Mozambique	Sweden
Cambodia	Honduras	Myanmar	Switzerland
Cameroon	Hungary	Namibia	Syrian Arab Republic
Canada	Iceland	Nepal	Tanzania
Central African	India	Netherlands	Thailand
Chad	Indonesia	New Zealand	Togo
Chile	Iran	Nicaragua	Trinidad and Tobago
China	Iraq	Niger	Tunisia
Colombia	Ireland	Nigeria	Turkey
Comoros	Israel	Norway	Uganda
Congo, Dem. Rep.	Italy	Oman	United Kingdom
Congo, Rep.	Jamaica	Pakistan	United States
Costa Rica	Japan	Panama	Uruguay
Cote d'Ivoire	Jordan	Paraguay	Venezuela, RB

Croatia	Kenya	Peru	Vietnam
Cuba	Korea, Dem. Rep.	Philippines	Yemen, Rep
Cyprus	Korea, Rep.	Poland	Zambia
Denmark	Lao	Portugal	Zimbabwe
Djibouti			

Note: This table lists the 137 countries for which the data on the growth rate of GDP per capita and TFR are available for each year from 1960 a 2022.
Source: Huang (2024)

Appendix 2: Full Results of Figure 2

Lag	Estimate	SE	Lag	Estimate	SE	Lag	Estimate	SE
L0	-0.0060	0.0022	L14	0.0020	0.0018	L28	0.0028	0.0030
L1	-0.0063	0.0022	L15	0.0029	0.0019	L29	0.0018	0.0030
L2	-0.0064	0.0021	L16	0.0039	0.0021	L30	0.0016	0.0029
L3	-0.0064	0.0021	L17	0.0050	0.0023	L31	0.0018	0.0028
L4	-0.0063	0.0021	L18	0.0061	0.0025	L32	0.0016	0.0027
L5	-0.0060	0.0021	L19	0.0070	0.0027	L33	0.0015	0.0027
L6	-0.0055	0.0021	L20	0.0078	0.0029	L34	0.0013	0.0028
L7	-0.0047	0.0020	L21	0.0084	0.0031	L35	0.0005	0.0030
L8	-0.0038	0.0020	L22	0.0086	0.0032	L36	0.0000	0.0032
L9	-0.0027	0.0019	L23	0.0084	0.0032	L37	0.0002	0.0034
L10	-0.0017	0.0019	L24	0.0079	0.0031	L38	0.0000	0.0037
L11	-0.0006	0.0018	L25	0.0069	0.0030	L39	-0.0006	0.0039
L12	-0.0003	0.0018	L26	0.0055	0.0029	L40	-0.0008	0.0041
L13	0.0012	0.0018	L27	0.0043	0.0029			

Note: All the estimated coefficients of fertility from model (2), with a length of 40 lagged years.

Appendix 3: Low and High Fertility Countries

Low-fertility countries		**High-fertility countries**	
Albania	Italy	Afghanistan	Mali
Argentina	Jamaica	Bangladesh	Mauritania
Australia	Japan	Benin	Mexico
Austria	Korea, Dem. Rep.	Bolivia	Mongolia
Barbados	Korea, Rep.	Botswana	Morocco
Belgium	Lebanon	Burkina Faso	Mozambique
Bosnia	Lesotho	Burundi	Namibia
Brazil	Macedonia	Cabo Verde	Nicaragua
Bulgaria	Malta	Chad	Niger
Cambodia	Mauritius	Colombia	Nigeria
Cameroon	Montenegro	Comoros	Oman
Canada	Myanmar	Costa Rica	Pakistan
Central African	Nepal	Cote d'Ivoire	Paraguay
Chile	Netherlands	Djibouti	Peru
China	New Zealand	Dominican Republic	Philippines
Congo, Dem. Rep.	Norway	Ecuador	Rwanda
Congo, Rep.	Panama	Egypt, Arab Rep.	Sao Tome and Principe
Croatia	Poland	El Salvador	Saudi Arabia
Cuba	Portugal	Ethiopia	Senegal
Cyprus	Puerto Rico	Gambia	Sierra Leone
Denmark	Romania	Ghana	St. Lucia
Equatorial Guinea	Russian Federation	Guatemala	Sudan
Finland	Singapore	Haiti	Swaziland
France	Slovenia	Honduras	Syrian Arab Republic
Gabon	South Africa	Iran	Tanzania
Germany	Spain	Iraq	Thailand
Greece	Sri. Lanka	Jordan	Togo
Guinea	Sweden	Kenya	Tunisia
Guinea-Bissau	Switzerland	Lao	Turkey
Hungary	Trinidad and Tobago	Liberia	Uganda
Iceland	United Kingdom	Libya	Venezuela, RB
India	United States	Madagascar	Yemen, Rep.
Indonesia	Uruguay	Malawi	Zambia
Ireland	Vietnam	Malaysia	Zimbabwe
Israel			

Prompts List

- "Help me turn this idea that I wrote in a more understandable way for those how read without don't compromising the main message of this theory"
- "How do I compute the accumulated effect according with the formula provided by this article"
- "Help me generate a code in STATA that can allow me to divide countries according with the median fertility rate in the year 1960."
- "Remember me the again the formula of the intervals of confidence so that I can compute it in the excel"
- "I am not understanding the equations from mentioned by Huang in his article. Could you enlighten me?"
- "This command in STATA is giving me an error. How can I solve this error?"
- "What is the advantage and disadvantage of this Newey-West and clustered standard errors?"
- "Could the demographic dividend not be verified in countries where the growing work force tends to be integrated in economy sectors that don't contribute significantly for GDP?"
- "In which conditions can occur the capital dilution mentioned in the neoclassical growth theory of Robert Solow?"
- "Does this description of the dynamic pattern graph coherent?"