Population growth and economic growth: a panel causality analysis [1]

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Abstract

This paper examines the relationship between population growth and economic growth using panel data for 111 countries over the period 1960 - 2019. In a first stage of the analysis, using a non-parametric method, we divided the sample into three groups of countries, obtained from objective criteria and not from ad hoc decisions such as size or economic performance used in some previous studies. From these groups that are internally homogeneous (made up of countries with similar trajectories for population growth and economic growth) and clearly differentiated from each other, we perform a Granger causality analysis. Our results show that there are relevant qualitative differences in the dynamics of population growth and economic growth between groups

Keywords: time series analysis; minimal spanning tree; hierarchical tree; population dynamics; economic growth; panel causality test.

JEL classification : C10; C14; C38; J10; O40

Introduction

The links between population growth and economic growth have long been the subject of debate among economists, demographers, and policymakers. The central axis of the discussion has revolved around the potential effects of (rapid or slow) population growth on economic growth and welfare. Despite the long history of the discussion, there is no agreement from the theoretical point of view about how they are linked, through which channels and which causes and effects. The abundant empirical literature that studies the subject does not help to resolve the controversy and it is difficult to find a unanimous result.

The population is an actor and object of economic growth, a substantial fraction of it constitutes the "work force", one of the productive factors behind economic growth. At the same time, the ultimate goal of growth is to raise the general welfare of the population. Understanding how the dynamics of these two variables are linked is fundamental to understanding the phenomenon of growth. Nevertheless, no consensus has emerge on whether population growth is beneficial, neutral, or detrimental to economic growth. There is also no consensus on the effects of economic growth on population dynamics –but this topic or causation direction has received much less attention in the literature.

Modern growth theories treat population differently from the classics. Generally speaking, standard growth models abstract out the role of population by assuming it to be an exogenous variable that grows at a fixed rate. Solow's model (Solow, 1956) predicts a negative relation between population growth rate and per capita income. In the long run, the higher the population growth rate, the lower the steady-state per capita output. In the short run, the higher the population growth rate, the lower the growth of per capita output during the transition to the new steady state equilibrium. The model does not differentiate population from labor force, implicitly assuming that both grow at the same rate or in a different way, that the population structure is stable. In this setting, the assumption of decreasing marginal returns results in a stable or fixed per capita output. Sustained growth could only be achieved by sustained technological progress.

Some endogenous economic growth models (Romer, 1986, Romer, 1990), in turn posit a positive relation between population and economic growth. In those models, population is not just a proxy for the labor force, but the source of scientists and innovators. The more of them, the more technological progress. At the same time, a larger population generates a higher demand for innovative goods, which in turn alters the human capital endowment, resulting in higher productivity (Kuznets, 1967, Kremer, 1993, Simon, 1989). This approach departs from previous efforts to model economic growth by allowing for controversial "scale effects".

Other theoretical approaches pick up the classic's approach of considering population as an endogenous determined variable. Hansen & Prescott, 2002, Irmen, 2004, Musa, 2015, Corchón, 2016, and more recently Bucci, Prettner & Prskawetz, 2019, among others, developed models where the relation between population growth and economic growth is nonmonotonic, with effects changing in size, sign and direction.

On the empirical front, Granger causality and cointegration analysis (Granger, 1969), (Engle & Granger, 1987) and the publication of the Maddison project's Penn tables, in particular Maddison, 1995, provided considerable impetus to comparative analysis of interaction between population and economic growth. When it comes to the empirical literature on the interplay between economic growth and demographic change, there is a strong focus on testing for cointegration between the two variables and studying their causal relations. To contextualize our research, we provide a brief review of this literature summarized in table 1.

It identifies various channels through which rapid population growth would have negative effects on economic growth. It reduces savings rates and the capital-labor ratio (dilution effect), increases the dependency rate, puts pressure on health, education and social protection systems, in addition to the effects on the environment.

At the same time, the potential positive effects are recognized. A growing population is a stimulus to demand and allows taking advantage of economies of scale as well as being a source of innovation.

Table 1

Empirical literature surveyed

Autor	**Period**	**Sample**	**Estimation Method**	**Findings**
Jung et al , 1986	1950 - 1980	44 countries	Granger Causality test	$p \Rightarrow^{+} y$ $p \Rightarrow^{-} y$ $y \Rightarrow^{+} p$ $y \Rightarrow^{-} p$ No causality
Kapuria-Foreman, 1995	1961 -1991 1961 -1990 1953 -1989 1951 -1990 1953 -1989 1961 -1991 1949 -1991 1952 -1991 1961 -1990 1961 -1990 1951 -1990 1958 -1990 1961 -1990 1952 -1990 1948 -1986	Nepal India China Ghana Sri Lanka Bolivia Philippines Guatemala Syria Peru Thailand Turkey Chile Argentina Mexico	Granger Causality test	$p \Rightarrow^{+} y$ $p^{+} \Leftrightarrow^{-**} y$ $p^{-} \Leftrightarrow^{+**} y$ $y \Rightarrow^{-} p$ $y \Rightarrow^{-} p$ No Causality No Causality $p \Rightarrow^{+**} y$ $y \Rightarrow^{-} p$ $y \Rightarrow^{-*} p$ No Causality $p^{-} \Leftrightarrow^{+**} y$ $p^{-} \Leftrightarrow^{+**} y$ No causalidad $p \Rightarrow^{+**} y$
Nakibulla, 1998	1960 - 1990	Bangladesh	VAR	$y \Rightarrow^{+} p$
Dawson et al, 1998	1950 - 1993	India	Cointegration (Johansen)	No Causality
Darrat et al, 1999	1950 - 1996	20 countries	Co-integration VEC	$p \Rightarrow^{+*} y$
Thornton, 2001	1900 – 1994 1925 -1994 1921 - 1994 1913 - 1994	Argentina, Brazil Chile, Venezuela Colombia Mexico Peru	Granger Test VAR	No Causality
		Japon, Korea, Thailand		$p \Leftrightarrow y$

Autor	Period	Sample	Estimation Method	Findings
Tsen, 2005	1950 - 2000	China, Singapore, Philippines Honk Kong, Malaysia Taiwan, Indonesia	Co-integration (Johansen) VAR	p ⇒ y y ⇒ p No Causality
An et al, 2006	1960 - 2000	25 OCDE countries	cross-country regression non-parametric kernel	relation inverted U-shape
Faria et al, 2006	1950 - 2000	125 countries	OLS (logy) (logy)2	Africa - Asia U-shape inverted Europe: y ⇒− p
Yao et al, 2007	1954 - 2005	Taiwan	Co-integration (Johansen), VAR, Toda-Yamamoto	until 2000 p ⇒+ y until 2005 insignificant
Azamhou et al, 2008	1960 - 2000	110 countries	GAM non parametric	
Afsal, 2009	1950 - 2001	Pakistan	OLS	Effect negative (p ⇒ y)
Choudry, 2010	1961 - 2003	China India Pakistan	OLS	Effect positive (growth differential pop of working age - total pop) 46% 39% 25%
Mulok, 2011	1960 - 2009	Malaysia	Co-integration (Johansen), VAR, Toda-Yamamoto	No Causality
Yao, 2013	1952 - 2007	China	Co-integration, VECM	p ⇒− y
Liu et al, 2013	1983 - 2008	provinces China (panel)	OLS	p ⇒− y
Huang et al, 2013	1980 - 2007	Panel 90 countries	simultaneous ADL	p ⇒− y
Song, 2013	1965 - 2009	13 countries Asia	OLS	Effect negative (p ⇒ y)
Ali et al, 2013	1975 - 2008	Pakistan	ARDL	p ⇒+ y
Furuoka, 2013	1960 - 2007	Indonesia	Co-integration (Johansen)	p ⇒+ y
Chang, 2014	1870 - 2013	Finland, France, Portugal, Sweden Canada, Germany, Japan, Norway, Switzerland Austria, Italy Belgium, Denmark, Netherlands, UK, US, New Zealand	Panel Granger Causality Test	p ⇒+ y y ⇒− p p ⇔ y No Causality

Autor	**Period**	**Sample**	**Estimation Method**	**Findings**
Musa, 2015	1980 -2013	India	Co-integration (Johansen), VEC	p ⇒+* y
Garza el al, 2016	1962 - 2012	Mexico	VEC	p ⇔ y
Sibe et al, 2016	1960 - 2013	30 of the most Populated Countries	VEC	p ⇔ y
Rahman et al, 2017	1960 - 2013	USA, UK, Canada China, India, Brazil	Panel co-integration VEC	p ⇒+ y
Alvarez-Diaz et al, 2018	1960 – 2010	28 states of the European Union	ARDL	p ⇔ y
Furuoka, 2018	1961 - 2014	China	ARDL	p ⇔ y
Aksoy, 2019	1970 - 2014	21 OECD countries	Panel VAR	p ⇒+ y
Mahmoudinia, 2020	1980 - 2018	57 Islamic countries	Co-integration (Johansen) VEC	p ⇒+ y
Sebikabu et al, 2020	1974 - 2013	Rwanda	ARDL	p ⇒+ y

Source: Own elaboration

Empirical research on the links between economic growth and population growth does not reach conclusive results and the differences are substantial, in terms of causal relationships (a la Granger), all possible results are found:

a) p ⇒ y, unidirectional causality, population growth stimulates economic growth: Darrat et al (1999), Yao et al (2007), Liu et al (2013), Ali et al (2013), Furuoka (2013), Musa (2015), Sebikabu et al (2020)

b) y ⇒ p, unidirectional causality, economic growth stimulates population growth: Nakibulla (1998),

c) p ⇔ y, bidirectional causality, population growth stimulates and is stimulated by economic growth: Garza el al (2016), Alvarez-Diaz et al (2018), Furuoka (2018)

d) No Causality, population growth neither stimulates nor is stimulated by economic growth: Dawson et al (1998), Thornton (2001), Mulok (2011)

e) mixed results: Jung et al (1986), Kapuria-Foreman (1995), Tsen (2005), Chang (2014)

Note that a large majority of the surveyed studies use a particular country or a group of countries as the unit of analysis, but studied individually (in general, highly populated developing countries). The relatively few studies that use a panel, the criteria used to form it is ad hoc, the size of the population (Sibe et al (2016), Rahman et al (2017)) belonging to an economic bloc (Alvarez-Diaz et al (2018), Aksoy (2019)), or cultural (Mahmoudinia (2020)). The criteria used to group may affect the results. In our article, in the first stage of the analysis, we present a non-parametric technique that allows us to compare the dynamics of demographic growth and economic growth of a large sample of countries, in order to obtain homogeneous groups through a statistical criterion built from the data. Once the clusters are defined, an econometric model is specified for each cluster in a panel data context. This allows us to overcome one of the main disadvantages of the standard panel data structure, which, in the presence of heterogeneous countries, is not always appropriate. In addition to adding temporal information, it allows taking into account the transversal dependency.

The paper is organized as follows. In the next section, we provide a brief review of the empirical literature on the relations between economic growth and demographic change. The following sections describe the clustering methodology used to divide the sample into groups of homogeneous countries, and the panel causality test applied in the study. Then we present the data and empirical results and in the last section contains our concluding remarks

Data and methodology.

Data

In this study, the population and economic growth dynamics are represented by the evolution of the population growth rate and per capita GDP growth rate respectively. Annual data of per capita GDP (in 2011 constant dollars, ppp adjusted), population and the corresponding growth rates are obtained from the Penn Word Table 10.0 [31][5] database, which

[5] available for download at www.ggdc.net/pwt

is considered the standard data source when it comes to comparative economic growth. The dataset includes annual data for 111 countries during the period 1960 – 2019[6].

During the period of analysis, aggregate world population exhibits a clear trend.

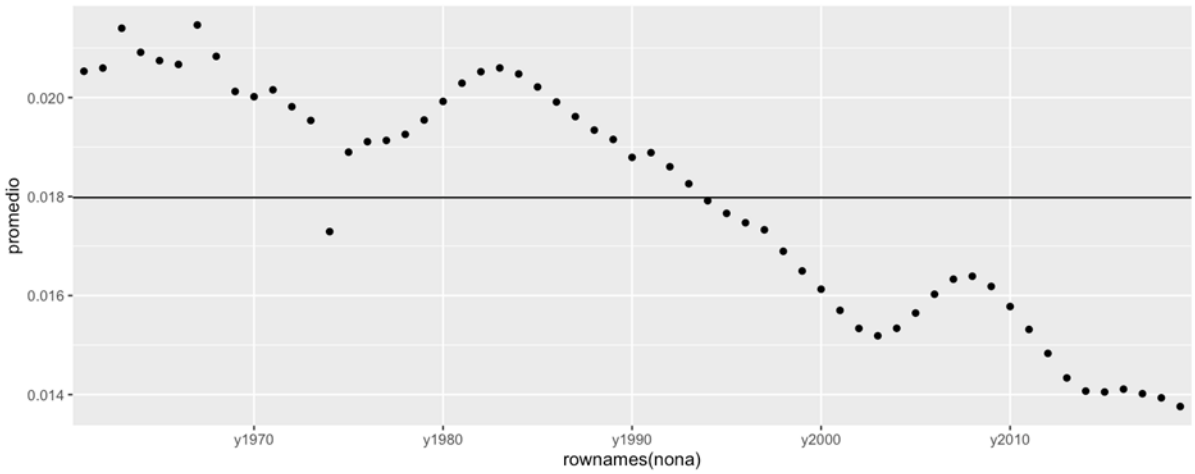


Figure 1: Population growth rate. Source: Own calculations based on pwt 10.0

As figure 1 shows, the total world population grows at a decreasing rate. Slow evolution, with a marked trend, without great variations in its growth rate. This is consistent with the stylized facts of the demographic transition. The trend however averages out wide disparities between countries in terms of the timing of their demographic transition and the speed with which each stage passes. Such disparities are the focus of this study. The average growth rate of population and growth rate of per capita GDP across the period of analysis are almost indistinguishable: 1.8% and 1.84% respectively. But the similarities end there. Average GDP per capita growth does not have a trend (see as figure 2), its standard deviation is 8 times bigger than the one from the population growth rate, and is pretty erratic, volatile in the short run, it's mean inter-annual variation is more than 40 times larger than that.

[6] Since our analysis requires a balanced panel, we opted to consider all countries that did not have missing data after 1960.

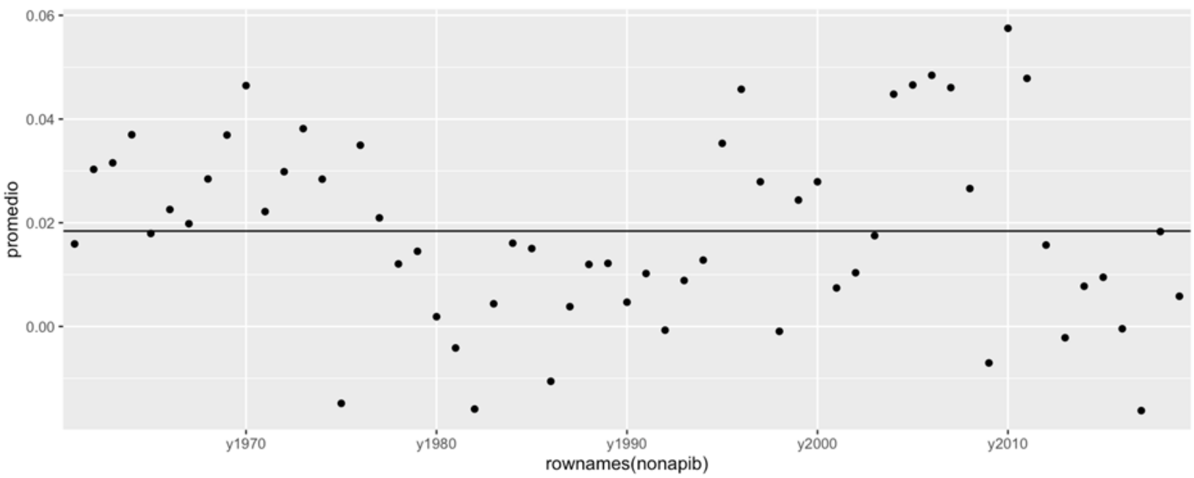


Figure 2: Average GDP per capita growth. Source: Own calculations based on PTW 10.0

Methodology

In this article, we propose a two-stage approach to examine the causal relationship between population growth and economic growth using panel data. In the first step, we use a non-parametric methodology to divide the sample into groups of homogeneous countries according to their dynamics in population growth and economic development, two factors that influence the causal relationship between them. In the second stage, we test causality by applying the procedure proposed by Dimitrescu and Hurling (2012).

Dimitrescu and Hurling (2012) extend Granger's (1969) causality test, originally proposed for time series, to panel data contexts. In addition, in this case the existence of heterogeneous effects between observational units is allowed. This allows us to test the existence of a causal relationship between population growth and GDP growth across different clusters of countries. Dimitrescu and Hurling's (2012) test is based on the cross-section average of individual Wald statistics associated with the standard Granger (1969) causality tests. These authors propose to test the non-causality null hypothesis against the alternative of causality hypothesis. Under the null hypothesis there is no causal relationship for any of the countries of the panel. An advantage of this test is that it allows to account for cross-sectional dependence proposing a block bootstrap procedure to correct the empirical critical values. It is important to take into account this dependency because ignoring it can lead to substantial bias and size distortions (Albadalejo et al., 2022).

In order to address the sign of this cause-effect relationship, impulse-response functions, which show the dynamic reaction of one variable to innovations in another variable, are used. These functions are estimated by applying a GMM panel VAR approach to the groups of countries where Granger causality is found. Our impulse response analysis assumes that the error terms are orthogonal with unit variance. Thus, a shock only occurs in one variable at a time, and since the variances of the error terms are one, a unit shock is just an innovation of size one standard deviation.

Empirical analysis, first step: cluster analysis: countries with similar dynamic behavior

To find homogeneous countries groups in relation to their dynamic behaviours in population growth and economic growth, the suggested method by Brida et al. (2020) is used. The method consists of an analysis of hierarchical conglomerates and using a metric that allows us to compare the dynamic trajectories of the different countries. This metric is constructed through a symbolization process, which involves transforming the original two-dimensional series defined by the dynamic trajectories in the population growth rates and GDP per capita growth rates of the different countries into a symbolic series that identifies the changes in the economic regime of the countries.

To describe the qualitative behavior of the joint evolution of economic and demographic growth, we introduce the notion of regime (Brida et al, 2003, Brida & Punzo, 2003) . A regime is a range of conditions characterizing the behavior of a system. For the purpose of our study, one that characterizes the joint dynamics of population and per capita output. We define two conditions, one sets a threshold for yearly population change and the other one sets a threshold for yearly change in rate of growth of per capita GDP. This results in a partition of the state space into four regions. If each region corresponds to a different relation between demographic change and economic performance (a different regime). Taking the average change in per capita income and population during the analysis period for all countries, the result is the following partition of state space into four regions:

$$R_1 = \{(g_p, g_y): g_p \geq \mu_p, g_y \leq \mu_y\}$$

$$R_2 = \{(g_p, g_y): g_p \geq \mu_p, g_y \geq \mu_y\}$$

$$R_3 = \{(g_p, g_y): g_p \leq \mu_p, g_y \geq \mu_y\}$$

$$R_4 = \{(g_p, g_y): g_p \leq \mu_p, g_y \leq \mu_y\}$$

If we label each regime R_i by the symbol j, we can substitute the original bi-variate time series $\{(g_{1p}, g_{1y}), (g_{2p}, g_{2y}), \dots, (g_{Tp}, g_{Ty})\}$ by a sequence of symbols $\{s_1, s_2, \dots, s_T\}$ such that $s_t = j$ if and only if (g_p, g_y) belongs to R_j

This Symbolic Series that summarizes the most relevant qualitative information on the dynamics of a country's regime[7].

When working with regime dynamics represented by symbolic sequences, we need to measure distances between symbolic sequences. Then, given two countries, i and j, with symbolic sequences $\{s_{it}\}_{t=1}^{t=T}$ and $\{s_{jt}\}_{t=1}^{t=T}$, corresponding to countries i and j, we define the following distance:

[7] See Brida et al, (2003) and Brida & Punzo, (2003) for a more detailed exposition of regime dynamics and its symbolic representation. In Brida, (2011) you can be found an empirical analysis on convergence clubs that apply the same approach as the one used in our paper.

$$d(i,j) = \sqrt{\sum_{t=1}^{T} f(s_{it}, s_{jt})}$$

Where

$$f\left(s_{it}, s_{jt}\right) = \{1\ if\ s_{it} \neq s_{jt}\ 0\ if\ s_{it} = s_{jt} \quad \forall\, i \neq j, \forall\, t.$$

Intuitively, the more coincidences two countries have in the same regime, the smaller their distance. When two countries exhibit the exact same sequence of regimes, they reach the minimum possible distance which is zero. The maximum possible distance is ($\sqrt{T}$) and it happens when two countries never coincide on the same regime in any year.

After calculating all the distances from the symbolic series of all the countries in the sample, we apply the Hierarchical Tree (HT) conglomerate technique to classify the countries in our study. To build this tree we employ the nearest neighbor single link clustering algorithm as described in Mantegna (1999); Mantegna and Stanley (2000)

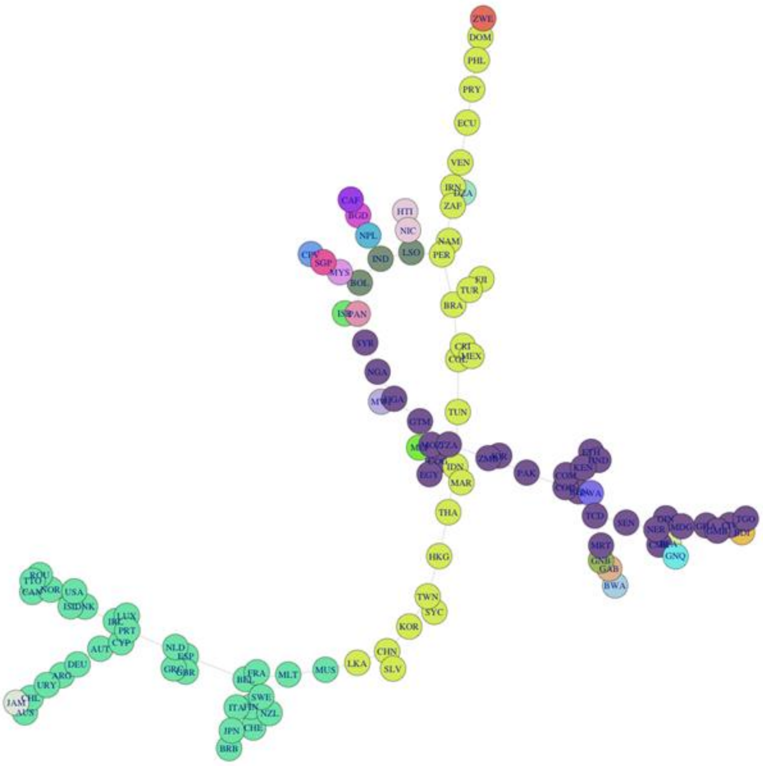


Figure 3: MST. In light blue the cluster of *mature economies*, in yellow that of *transition economies*, in violet that of *young economies*, the rest of the countries have trajectories that do not fit the previous patterns.

The MST and the matrix D^* allows us to compute the subdominant ultrametric distance matrix, which is the prerequisite to build the HT). Figure 4 shows the dendrogram that represents the HT obtained.

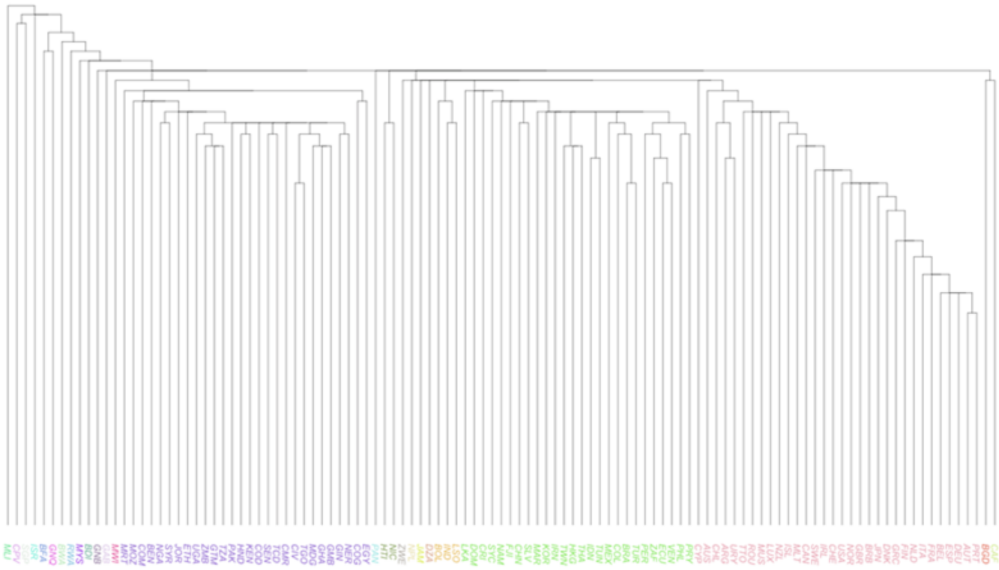


Figure 4: Hierarchical Tree.

Given a number of groups in which we want to divide the sample, the HT shows how countries should be grouped. That is, if you want to partition the sample into eight groups of countries, then you can use the HT to determine which countries go in each group. The final step then is to apply a hierarchical clustering stopping rule to find the optimal number of groups. The application of the C-Kalisky rule results in 3 well differentiated clusters containing 87 of the 111 countries (approximately 80% of the countries in the sample).

The first group, that we have called *mature economies*, contains 32 countries and is the most homogeneous of the three. The sum of the group distances in the MST is the smallest one. The group includes all 24 of the initial members of the OECD except for Turkey[8] . The non-OECD countries in the group (Argentina, Barbados, Malta, Mauritius, Trinidad y Tobago,

[8] By initial members, we mean the countries that joined the organization in its first decade or so of existence.

Rumania, and Uruguay) are currently classified as upper income or upper middle income countries. In terms of regime dynamics, the common denominator in this group is that they almost strictly alternate between regimes R_3 and R_4 during the entire period of analysis. Some countries in the group such as Canada, Chile, or Trinidad Tobago have a short initial phase alternating between R_1 and R_2 (but concentrated in R_2) that extends at most for the first decade and a half of the period of analysis[9]. In short this group comprises countries that transitioned from high to low population growth before the period of analysis or in a few cases at the beginning of the period of analysis (before the mid-1970s).

The second group, which we call *young economies*, containing 28 countries, is the most heterogeneous of the three that we obtained. It includes 22 Sub-Saharan African countries, 3 middle eastern countries (Egypt, Jordan and Syria), 2 Central American countries (Guatemala and Honduras) and Pakistan. Continuing with the pattern observed in the previous cluster, the defining character of the countries in this group is that during the period of analysis, they alternate almost entirely between regimes R_1 and R_2, mirroring the dynamics of the mature economies cluster. Of the 28 countries in this group, 16 of them never never visited regimes R_3 and R_4. Mauritania, Mozambique, and Syria, are the cases where it would be possible to talk about a short phase in the R_3 and R_4. Mauritania in the 1960s, Mozambique during the 1980s and more recent, in the last decade, Syria. The Syrian anomaly has to do with the population displacement resulting from the civil war that started in 2011.

Broadly speaking, countries in group 3, which we have called *transition economies*, exhibit two distinct phases. In the first one, countries alternate between regimes R_1 and R_2. In

[9] Three countries in the group, Australia, Ireland, and Luxembourg have some years alternating between R1 and R2 in the final 15 years of the analysis. One possible explanation: the relatively high influx of immigrants during those years. In fact, as a percentage of their population, these countries received the most immigrants in the group during the last two decades.

the second phase countries alternate between regimes R_3 and R_4. There is variation in terms of the moment countries switch between phases. The two extreme cases are Korea, which moves to the second phase as early as the late 1970s, and Philippines, which does not switch phases until the midaughts. There is also variation in terms of the proportion of above average economic growth years in each phase. In the first phase for example, is very low for Namibia, Venezuela, and Ecuador and very high for Taiwan and Korea. The common denominator in the 26 countries that comprise this group is that they transition from high to low population growth during the period of analysis. The group includes many of the countries that were able to capture the demographic dividend during the period of analysis (a marker of this appear to be time spent in the regions R_2 and R_3).

Second step: panel causality analysis

Table 2 below shows the results of the Granger causality test for the panel of countries. From there it can be seen that, when considering the complete sample, a bidirectional causal relationship emerges between population growth and GDP per capita growth. The p-value associated with the test statistic suggests rejecting both null hypotheses. This indicates that higher population growth increases GDP growth per capita and vice versa.

When disaggregated by cluster of countries, the results are similar: once again a bidirectional causality relationship emerges between population and GDP. The exception is Cluster 1(*mature economies*): in this group of countries, higher population growth does not translate into higher GDP growth.

Table 2

	Complete panel	Cluster 1	Cluster 2	Cluster 3	Lags
H0: population growth does not Granger-cause GDP per capita growth					
Statistic	6,5169***	0.4651	5,8346***	3,0955***	17
H0: GDP per capita growth does not Granger-cause population growth					
Statistic	8,8681***	6,6236***	4,9418***	2,0667**	17

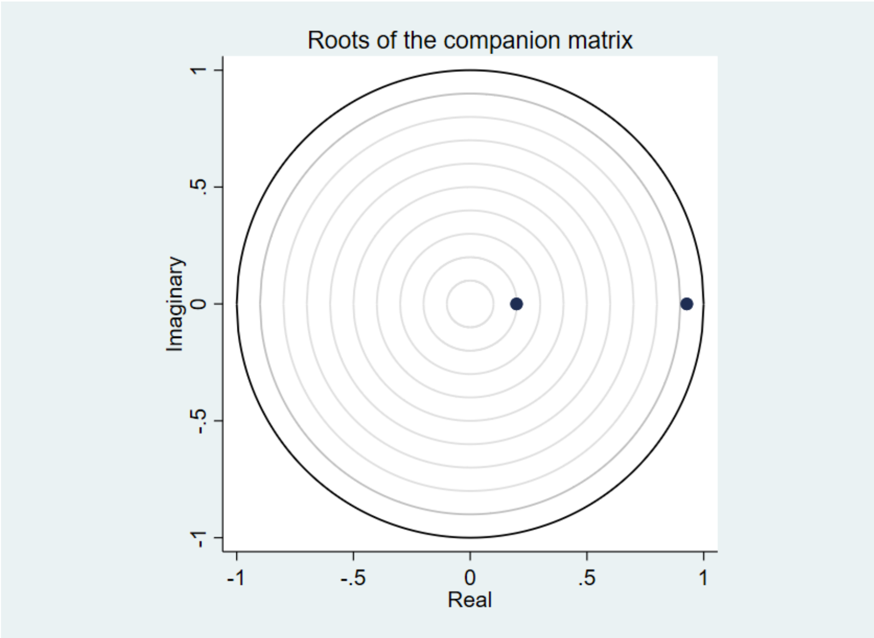
Source: Own elaboration based on Penn Tables. Note: the number of lags arises from the optimization of the Akaike information criterion (AIC).

The above result has interesting implications. While countries in Cluster 1 (*mature economies*) have few incentives to promote their population growth (given that it does not translate into a higher income), countries in Clusters 2 (*young economies*) and 3 (*transition economies*) do have clear incentives to do so. This could mean that countries in Cluster 1 have an aging and declining population, while those in Clusters 2 and 3 have accelerated population growth. This is consistent with global migratory flows: countries of Cluster 1 (high income) have a reduced natural growth -negative in some cases- and receive constant migratory flows from countries of Clusters 2 and 3 who have a higher natural growth.

Impulse response analysis

After verifying the existence of a bidirectional causal relationship between population growth and GDP per capita growth, we now examine the sign of that causality from impulse-response functions. *Graph 1 shows that the series considered in the panel VAR model meet the stability condition (i.e. stationarity) given that the eigenvalues are included within the unit circle.*

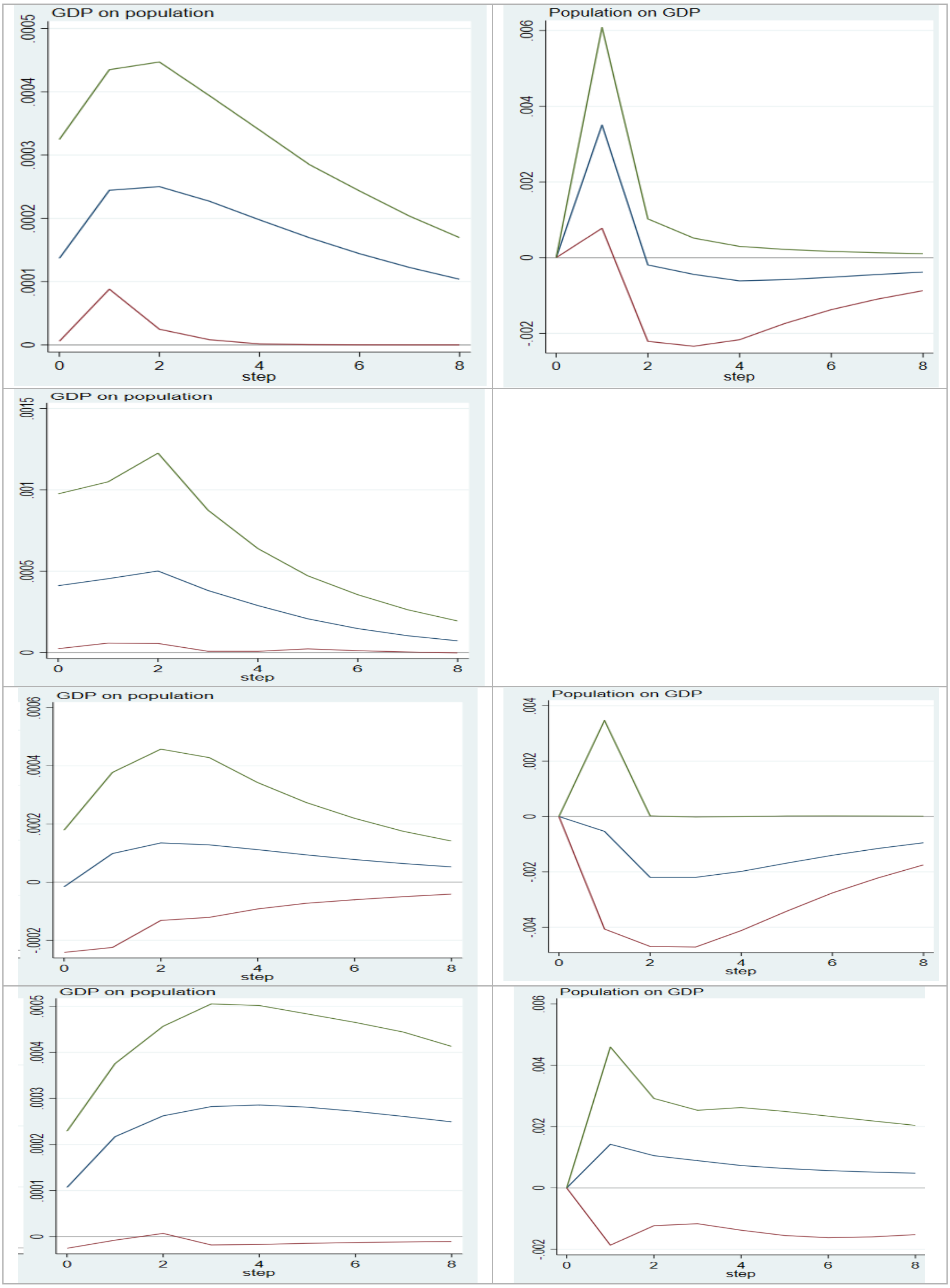
Graph 1: Stability condition for panel VAR



Source: Own elaboration based on Penn Tables. Note: All the eigenvalues lie inside the unit circle, the panel VAR model satisfies stability condition.

Graph 1 shows that a shock in one of the variables (impulse) gives rise to an increase (response) in the other. This suggests that the association between both variables is positive (higher population growth is associated with higher GDP growth, and vice versa). However, the observed increase disappears after a few periods or is even statistically insignificant in some cases.

Figure 5: Impulse-responses for 2 lags VAR of population growth and GDP growth



Source: Own elaboration based on Penn Tables. Note: from top to bottom each row refers to: full panel, Cluster 1, Cluster 2 and Cluster 3.

Concluding remarks

The study of relations between economic and population growth has a long pedigree in economics. However, from a theoretical point of view, there is no agreement about the scope and channels through which population and economic growth affect each other. Empirical evidence does not help save the controversy. From the large volume of empirical studies that address the subject, no unanimous conclusion emerges and on the contrary, results are contradictory. Based on this great variety of results revealed in the literature, we opted, in a first stage, to obtain groups of countries that during the period of analysis have exhibited similar trajectories in terms of economic and population growth. Applying clustering techniques and previously introducing the notion of regime, we seek to identify groups of countries. Each of them internally homogeneous in terms of the dynamic relations between demographic change and economic growth and at the same time clearly distinct from the rest of the groups.

From this first exercise, we obtain three groups that we call *mature, young* and *transition economies based on their population and economic growth dynamics. Second, we study the existence of causal relationships between both dynamics (population and economic). Based on the procedure* proposed by Dimitrescu and Hurling (2012) for panel data contexts, we identify bidirectional causal relationships for the global panel of countries and for two of the three clusters (young and transition economies). However, in the case of mature economies (cluster 1), a causal effect from population growth to economic growth was not observed. Then, we proved that this causal relationship is positive from a VAR model for panel data. This imposes interesting implications and recommendations.

From an individual point of view, the foregoing implies that *mature economies* could be less open to receiving foreign migrants or to stimulating their domestic population growth, since this would not result in income gains. At the same time, *transition* and *young economies* may have incentives to accelerate their population growth. Ultimately, this may result in wide population imbalances in the developed and developing world, while deepening current concerns about migration flows.

In the future, it is essential to have a balanced panel of countries for which population and GDP data exist. In addition, the analysis could be deepened by incorporating controls that can influence the dynamics of some of these variables, as well as other methodologies frequently used in the literature.

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Appendix A

Table 5: Country Codes

ARG	Argentina	GAB	Gabon	NAM	Namibia
AUS	Australia	GBR	United Kingdom	NER	Niger
AUT	Austria	GHA	Ghana	NGA	Nigeria
BDI	Burundi	GIN	Guinea	NIC	Nicaragua
BEL	Belgium	GMB	Gambia	NLD	Netherlands
BEN	Benin	GNB	Guinea-Bissau	NOR	Norway
BFA	Burkina Faso	GNQ	Equatorial Guinea	NPL	Nepal
BGD	Bangladesh	GRC	Greece	NZL	New Zealand
BOL	Bolivia	GTM	Guatemala	PAK	Pakistan
BRA	Brazil	HKG	China, Hong Kong SAR	PAN	Panama
BRB	Barbados	HND	Honduras	PER	Peru
BWA	Botswana	HTI	Haiti	PHL	Philippines
CAF	Central African Republic	IDN	Indonesia	PRT	Portugal
CAN	Canada	IND	India	PRY	Paraguay
CHE	Switzerland	IRL	Ireland	ROU	Romania
CHL	Chile	IRN	Iran	RWA	Rwanda
CHN	China	ISL	Iceland	SEN	Senegal
CIV	Côte d'Ivoire	ISR	Israel	SGP	Singapore
CMR	Cameroon	ITA	Italy	SLV	El Salvador
COD	D.R. of the Congo	JAM	Jamaica	SWE	Sweden
COG	Congo	JOR	Jordan	SYC	Seychelles
COL	Colombia	JPN	Japan	SYR	Syrian Arab Republic
COM	Comoros	KEN	Kenya	TCD	Chad
CPV	Cabo Verde	KOR	Republic of Korea	TGO	Togo
CRI	Costa Rica	LKA	Sri Lanka	THA	Thailand
CYP	Cyprus	LSO	Lesotho	TTO	Trinidad and Tobago
DEU	Germany	LUX	Luxembourg	TUN	Tunisia
DNK	Denmark	MAR	Morocco	TUR	Turkey
DOM	Dominican Republic	MDG	Madagascar	TWN	Taiwan
DZA	Algeria	MEX	Mexico	TZA	Tanzania
ECU	Ecuador	MLI	Mali	UGA	Uganda
EGY	Egypt	MLT	Malta	URY	Uruguay
ESP	Spain	MOZ	Mozambique	USA	United States
ETH	Ethiopia	MRT	Mauritania	VEN	Venezuela
FIN	Finland	MUS	Mauritius	ZAF	South Africa
FJI	Fiji	MWI	Malawi	ZMB	Zambia
FRA	France	MYS	Malaysia	ZWE	Zimbabwe