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Linear and nonlinear causality between marriages, births and economic growth

Carmen Borrego-Salcido[1]
Universidad Autónoma de Coahuila, México
Raymundo Juárez-Del-Toro[2]
Universidad Autónoma de Coahuila, México
Salvador Cruz-Aké[3]
Instituto Politécnico Nacional, México

Abstract

This article represents the aim to identify the number of births as a forward-looking indicator regarding an economic crisis for Mexico and other countries with different levels of economic development. To state the supposed behavior of the number of births it was used simple graphical evidence, a Granger causality analysis and phase synchronization among a set of economic variables and life-long decisions such as having a baby and marriage. The results for all the studied countries showed an anticipated behavior from the number of births regarding important economic variables and some causal relations. The phase synchronization showed the absence of synchronization during crisis periods coinciding with the graphical evidence. Similar studies could consider other demographic variables such as divorce and suicide. Despite the availability and periodicity of data were the main limitations in this study and lead the selection of the studied economies, the phase synchronization had never been used with demographic variables before. Marriages result in not being relevant to determinate the number of births while the number of births resulted in a variable that fosters the GDP.

JEL Classification: C10, C14, G01, J11, J13
Keywords: Granger causality, phase synchronization, births, marriages, economic crisis

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Resumen

Este artículo representa el objetivo de identificar el número de nacimientos como indicador adelantado respecto a períodos de crisis para México y otros países con diferentes niveles de desarrollo económico. Para establecer el supuesto comportamiento del número de nacimientos, se utlizó evidencia gráfica simple, análisis de causalidad de Granger y sincronización de fase entre un conjunto de variables económicas y de decisiones de vida, tales como tener un bebé y matrimonio. Resultados para todos los países estudiados mostraron un comportamiento

[1]Correspondig Author: Blvd. Revolución 151 Ote., Col. Centro, 27000, Torreón, Coahuila, México. (+52) 871 712 6246. E-mail: carmen.borrego.salcido@hotmail.com ORCID: 0000-0002-6256-3592
[2]ORCID: 0000-0001-5500-4066
[3]ORCID: 0000-0003-1452-377X
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Resumen

anticipado del número de nacimientos respecto a variables económicas importantes y algunas relaciones causales. La sincronización de fase mostró ausencia de sincronización durante períodos de crisis, coincidiendo con la evidencia gráfica. Estudios similares pudieran considerar otras variables demográficas como divoricio y suicidio. A pesar de que la disponibilidad y periodicidad de los datos fueron las principales limitaciones de este estudio y condujeron la selección de las economías estudiadas, la sincronización de fase nunca antes había utilizada con variables demográficas. Matrimonios resultó no relevante para determinar el número de nacimientos mientras que éste resultó ser una variable que impulsa el PIB.
Clasificación JEL: C10, C14, G01, J11, J13
Palabras clave: causalidad de Granger, sincronización de fase, nacimientos, matrimonios, crisis economicas

1. Introduction

The Great Recession of 2007-2009 (as many other previous crises such as the Wall Street Crash of 1929, the early 1990's recession and the *Dotcom* bubble), has been the object of multiple studies (for a complete database of crises see Laeven & Valencia, 2013) that have established its causes and its effects. Many lessons were learned (such as the contagion channels) but as in many other crises, these lessons and the measures that prevent new downturns are not the same for all the countries due to the level of economic development and each country policies.

Since macroeconomic indicators have been identified as effective predictors of real economic activity (Estrella & Mishkin, 1998), it is important to emerging countries like Mexico, determine which indicators fit perfectly their economic behavior and could indicate an anticipated signal of crisis.

Buckles *et. al* (2018) proposed that a fall in the number of conceptions (despite the result of the conception: miscarriage, abortion or fetal death) could be a forward-looking indicator of a crisis for the U.S., but they were also conscious that it will need to be probed for other countries to find if it is a relevant indicator for each level of economic development. Therefore, this paper will replicate part of their study with the available data for Mexico and other economies. It is important to contrast results between the studies due to the differences in a developed economy and an emerging country. Verdickt (2019), also suggested that fertility is a leading indicator for recessions.

A forward-looking indicator for crisis is an econometric model which pretend to predict the probability of crisis considering all the variables presumably relevant for other authors (de Lis & Herrero, 2002). Therefore, we need to set which explicative variables could we consider for the study as the first step.

The hypothesis of the forward-looking behavior of the number of births (in the case of Mexico, the number of conceptions is not available, but we will discuss this later) is tested using two different approaches: a Granger causality analysis and a nonparametric one: the phase synchronization to state non-linear relationships between two studied variables to probe if the results are the same. As far as the authors of this paper know, this technique has never been used in the fertility literature.

As is was previously said, it is important to analyze the forward-looking behavior for different kinds of economies, therefore, the study for a sample of countries with different levels of development will be replicated in order to compare the results. For the sample of countries, the used data has a quarterly frequency.

This paper has 6 sections: previous studies about population and economy, a framework for the used techniques, graphical evidence for Mexico, the results for the Granger causality analysis, the results for the non-parametric approach, and the conclusions.

2. Previous studies about population and economy

Thomas Robert Malthus proposed in the 18th century, that the population has a geometric growth, but the production of food has an arithmetic growth. Therefore, there will be a moment in which the produced amount of food will be insufficient for feeding all the population, leading to a catastrophic situation in which part of the population will die from starvation. Malthus also considered that having children was a decision impulsed by the needing of the workforce for rural families and to ensure an income in old age (Mellos, 1988).

The Neo-Malthusian theory states that producing o acquiring goods is an unrestrained activity and it also includes to *produce* children, impulsed by unlimited desires related to individual freedom (Mellos, 1988).

In the 18th century, the Industrial Revolution boosted the population move from rural areas to industrialized cities and helped to partially deny the Malthusian theory due the mechanized processes helped to produce goods and food faster than in the past, avoiding the catastrophe predicted by Malthus.

Nowadays, fertility decisions can be considered as a rational act that involves the preferences and circumstances of the mother (Davia & Legazpe, 2013) and it is considered that raising a family implies costs (Becker & Barro, 1988, and Cerda, 2007). As can be seen, the number of children will depend positively on the income of the families, and negatively on the cost of each child (Cerda, 2007). Becker & Barro (1988) also recognized the relationship between the parent's income and the decision of having children. Therefore, if the families perceive a positive economic environment, will be aimed to conceive a baby, of way contrary, if they perceive a turmoil coming in, they will decide to not have a baby or to postpone the decision.

Brida (2008), stated that if a country presents a birth growth rate of 0 instead of a positive number, the economic behavior will improve in the long term. Lovenheim & Mumford (2013), used variations on the US housing market to prove that fertility is influenced by changes in this market. They also discovered that an improvement in the housing welfare causes a decrease in teenage births and that fluctuations in the housing market are a factor in fertility decisions.

Castillo-Ramírez, *et al* (2016) stated that the Mexican population presented an accelerated growth from 1930 to 1970. After that period, the growth decreased and for the beginning of the 21st century, it represents just half of the maximum growth. These results represent the aim of the government to reduce the growth rates through public policies of family planning. They discovered that an increase in public expenditure affects negatively the growth of the population, and an abrupt growth in the population causes a decrease in the capital per capita, therefore we can see that an economic decision also affects a lifelong one.

Ruiz-Porras & Valdés (2017) developed a study for Mexico that found that there is a relationship between natality and production that causes a virtuosos circle due to negative relationships in the long-term. Public policies for family planning promote economic development in long and short terms. Economic improvement tends to reduce birth rates.

Sobotka *et al* (2011), stated that economic recessions are a factor that affects decisions and dynamics in the families. It affects lifelong determinations such as fertility.

Verdickt (2019) performed a study for stock returns in the United States, concluding that "fertility growth negatively forecasts excess returns as of 18 months ahead", Verickt (2019, p.15).

Bellido & Marcén (2019) lead a study using quantile regression and finding an inverse relationship between unemployment and fertility, which becomes more pronounced for the lower quantiles of the fertility rate. For countries with lower fertility rates, a crisis became a factor that impacts even more in fertility decisions.

Seltzer, (2019), suggest that the labor market polarization has had a negative impact on the fertility rates during the 2000's decade and the years after the Great Recession, having this effect more pronunciation for Hispanic and African American women.

As a result of public policies to reduce the size of the families, in general, women of all levels of income

have had a decline in the number of children they decide to have, as in many other countries such as Canada, Germany, Italy, Luxemburg and the Netherlands (D'Addio & d'Ercole, 2005). It is something that we could consider a global trend, due to factors like a major number of women in the labor market, and higher educational level.

The access to health services, vaccines and the reduction of fetal and infant deaths have had an effect on the global trend of having fewer children due to the possibilities of survival.

Other important aspects affecting fertility are more access to education, a higher number of women that work and family planning programs. The lack of need economic support (due to social security) for old age has had a negative impact on the population growth rates.

This study pretends to prove the forward-looking behavior of the number of births regarding economic variables previously identified as relevant in the decision-making process of having a baby. It will be used three techniques: simple graphical evidence for the case of México, Granger causality analysis and phase synchronization for Mexico and four countries more. The last two techniques have never been used before with a set of demographic and economic variables and this study goes beyond further by incorporating the phase synchronization, a nonparametric approach used so far only for studies about capital markets and stock indices (García-Ruíz, 2014, and Cruz-Aké *et al*, 2012), food prices (Cruz-Aké, 2017), and commercial and industrial synchronization (Calderón-Villarreal *et al*, 2017) and the formation of speculative bubbles (Cantú-Esquivel, 2018), but never used before with demographic variables, constituting a valuable contribution to the understanding of the relationships between economic and demographic variables.

3. Methodology

This section presents an explanation of the used techniques: the simple graphical evidence, the Granger causality analysis, and the phase synchronization; as well as the process for the selection of the variables which integrate the models.

The study performed by Buckles *et al* (2018) also included the analysis of the number of abortions but in Mexico, it is legal only in Mexico City and the data is only available annually since 2007, therefore this variable is not considered as a determinant for a change in the number of births. Models for the other studied countries did not include this variable either.

In order to reduce the gap between real-time and data availability, it was changed the data frequency from the original study since in Mexico IGAE (Economic Activity General Index) is available monthly as well as the number of births and the other variables used in this paper. Using monthly available data increases the capacity of the model to show the behavior of the economy.

In order to compare the behavior of the number of births regarding economic variables, we selected a pool of countries with different levels of economic development: Germany, a fully developed economy; Chile, a Latin-American developing country; Singapore, one of the original "Asian Tigers"; and South Africa, the biggest economy in Africa. We also considered the data availability and the sample size for the selection. The data used for these countries has a quarterly frequency.

a) **The Graphical Evidence**

For the graphical evidence, it will be used the equivalent to the proposed variables used by Buckles *et al* (2018) regarding the selection of variables in section 2c: IGAE[4] (Economic Activity General Indicator), CCI4 (Consumer Confidence Index), and IPC Housing4 (Underlying Real Estate Index of Prices to Customer). These variables will be compared to the number of births.

[4]Source: Instituto Nacional de Estadística y Geografía (www.inegi.org.mx)

The number of births was used instead of the number of conceptions (or total fertility) due to in Mexico does not exist an official record of the gestation in weeks at the moment of the birth as on the US. Therefore, it is expected that in the graphical evidence, the falls in the indicators could vary from the showed by Buckles *et al* (2018) and the declines in the number of births could appear at the same time of a fall in the IGAE or the other used indicators.

The number of births as CCI and IPC Housing have a strong seasonal component, therefore it will be used the Census X-12 (a U.S. Census Bureau's software package included in EViews 9. For more information please check `http://www.eviews.com/help/helpintro.html#page/content/series-Seasonal_Adjustment.html)`, for seasonal adjustment in order to eliminate the seasonal component of the series and to be able to identify the trend and the real behavior of the series before and after the crisis, which in this case is the crisis of 2007-2009. IGAE was got seasonally adjusted from the original source.

As first evidence of the relation between the number of births and the proposed variables, it will be elaborated a graphic that compares the behavior of the time series.

b) **The Granger Causality Analysis**

It will be used a very popular econometric approach to state relationships among the used variables, suggested by Toda & Yamamoto (1995), which uses a Vector Autoregressive (VAR) model. A VAR model is accurate for stationary time series, but cointegration relationships (or long-term relationships) could not be shown in these kinds of model. Therefore, this methodology is capable to adapt the Granger causality test to cointegrated series, avoiding the problem originated by the order of integration of the variables and the co-integrant nature of the time series (Calderón-Villarreal, *et al*, 2017).

It will be also used the Vector Error Correction, (VEC, a VAR family kind of model) which is appropriated to identify linear relationships between non-stationary time series. This model will help to settle long-term relationships and will also show short-term relationships previously captured by the VAR model.

The preparation for the Granger causality test proposed by Toda & Yamamoto (1995) is to analyze each time series individually performing a KPSS test for stationarity in order to determinate each one's order of integration, being the maximum found order m=1, therefore, the order of integration for the set of variables is 1 (for each country). It is important for the calibration of the model to determine the order of integration because we will add the value of the order of integration of the set to the lags for the exogenous variables with a negative sign, following the Toda & Yamamoto (1995) methodology.

The VAR modeling process was the same for each country: to run a Wald test to find which variables are not significant for the model, to find the appropriated number or lags (avoiding the presence of unit root and looking for serial correlation in the residuals) and after that, to perform a Granger causality test. Then, to estimate a VEC model to show the long-term relationships among the variables and ran a second Granger causality test.

The specifications of the model for each country are presented in the result section with the appropriate number of lags and which variables are endogenous, which are exogenous, and which are not significant for each of the cases.

c) **The phase synchronization**

To contrast the results given by the Granger causality analysis, it was used the phase synchronization, a non-parametric technique to evaluate two non-deterministic systems and their similarities, (Cruz-Aké, 2017), which has its origins in the studies made by Christian Huygens in 1665. He discovered that two pendulums staying in the same surface, will synchronize their movements but this synchronization ends if

one of them is moved from the surface (Cruz-Aké *et al*, 2012, García-Ruiz, 2014 and Calderón-Villarreal *et al* 2018).

The synchronization is a phenomenon that makes reference to two dynamic systems that tend to adjust their movement and trajectory due to attractors. The most common methodologies to find out synchronization are by differential equations and by time series, identifying a master system and a slave one. These two systems will present identical oscillations after a period of time (García-Ruíz, 2014). The "controller" system (named master) is defined by the state vector $x_n = [x_1, x_2, \ldots, x_n]$ and an "observer" (named slave) which is an output from the master system (Cruz-Aké, *et. al.* 2012 and García-Ruiz, 2014).

There are four forms of synchronization: complete synchronization, which presents perfect union in the trajectories of two systems; generalized synchronization, in which the output of a system is in function of the input of a first one; phase synchronization, which present two non identical oscillators that present a weak correlation between their amplitudes; delay synchronization, which belongs to the intermediate point between perfect synchronization and phase synchronization (García Ruíz, 2014).

The objective of using this technique is to separate the time series in parts, getting the cyclical component which will allow to get the number of cycles present in each time series and to appreciate which of the time series is the master one and which series are slaves. It also lets us observe if the cycles occur at the same time which would give us a "perfect phase synchronization" between the studied variables.

It is needed to consider that a cycle has the form of a sinus function, and two changes in the signs represent a complete cycle when the line that describes this kind of function "touches" the zero twice: when it presents a fall and becomes negative, and when it raises getting a positive value again.

Now, the process for phase synchronization is described. time series will be compared in pairs: the number of births time series against each one of the other time series. The reason for doing this is that it is wanted to know how fertility is affected by the macroeconomic variables or vice versa. The steps will be the same for each studied country.

As a first step to prepare the time series for the phase synchronization, the seasonal component from the number of births and the number of marriages will be retired by using the Census Bureau's X12-ARIMA package within EViews 9.

Since the time series present different magnitudes (percentages, millions of dollars, etc.) the next step is to normalize the series, which consists on divide each value of the series between its maximum value, maintaining their movement properties.

The process for phase synchronization is described by the following function as in Cantú-Esquivel (2018):

$$X_t = (\varepsilon \times X_{t-1}) + (1 - \varepsilon)K_t \tag{1}$$

Where X_t represents the smoothed series, ε is the smoothing level, X_{t-1} represents the smoothed series lagged one period and K_t is the original time series.

After the smoothing process, calculate the phase differential for each pair of compared series using the formula

$$\Phi_X(t) = 2\pi(t - t_k)/(t_{k+1} - t_k) + 2\pi k \tag{2}$$

Where k represents the number of the cycle for the variable and $t_{k+1} - t_k$ corresponds to the duration of each period (Calderón-Villarreal *et al* 2017). The process will be repeated for each time series in order to get the differential of analyzed pair of series. When the differential is the same for each observation in the series, it means that the series are synchronized in phase. The series could be synchronized in phase, but

then lose that synchronization to recover it again or not. When the differential is the same for a period of time it represents strong synchronization, whereas if the difference between the differentials stays close to zero (but not zero) the series presents weak synchronization. After finding the phase differential it is possible to identify a master system and a slave one and replicates its behavior at the same time or with a delay.

d) **Selection of the variables**

The first variables were selected trying to represent lifelong desitions: having a baby (number of births); the number of marriages; and the changes of prices of the real estate market, represented by the IPC Housing. This last variable is also relevant to this study because of the nature of the Great Recession of 2007-2009 and it also involves a life-long desition due to the fact that most of the people need a long-term loan to purchase their houses.

Some macroeconomic variables are widely accepted as representatives of the performance of an economy: interest rates, foreign exchange rates, and industrial production (Muradoglu *et al*, 2000). Interest rate is vastly accepted as a variable to consider for the kind of studies that focus on crisis literature (Frankel & Saravelos, 2010).

The other variables were selected because of their very known relevance in macroeconomics literature: GDP (Gross Domestic Product, for the pool of studied countries), unemployment rate, interest rate, CCI and exchange rate. IGAE is a previous estimation of the GDP. It reflects the monthly evolution of the real economy, therefore, it is a short-term indicator.

The importance of the CCI and unemployment is supported by the fact that "the available evidence indicates that a change in unemployment or in consumer confidence matters more for fertility changes than the levels of these indicators". (Sobotka *et al* 2011, p. 291). CCI affects negatively fertility because of its properties to capture uncertainty (Shneider, 2015)

Buckles *et. al* (2018) proposed that fertility could be a forward-looking economic indicator and that the factor behind it have a rapid effect on the family decisions, specifically on the decision of having a baby or not. Their study compared fertility rates to other important indicators: the consumer confidence index, purchases of personal durable goods and growth in housing prices. They presented graphical evidence that fertility rates decreased rapidly before these other important indicators.

Prior authors have highlighted the importance of fertility and its behavior from an economic perspective. Fertility is procyclical and it responds to negative shocks (Jones & Schoonbroodt, 2016, and Sobotka *et al*, 2011, Buckles *et al*, 2018, Bellido & Marcén, 2019, Seltzer, 2019) and to unemployment with a decline (Currie & Schwandt, 2014). For men and women, unemployment has a negative effect on conceptions and negative changes in the income could have long-term effects on fertility (Andersen & Ozcan, 2011).

From an economic perspective, a son could be seen as a consumption good and a factor of production that could provide an income to their families (Becker, 1960) and (Del Río *et al*, 2010).

Income is considered as a factor that affects demographic behavior (D'Addio & d'Ercole, 2005), therefore the absence of it or a low one could be a determinant in childbearing decisions. Shocks in the level of income have long term effects on fertility (Andersen & Ozcan, 2011).

All selected macroeconomic variables for the model satisfy the NBER (National Bureau of Economic Research) criteria which consider the economic significance, the statistical reliability, a uniform behavior through the time, large coverage of the economy, smoothness of the series, timely availability and high frequency (Del Río *et al*, 2010). Macroeconomic variables are useful to observe the general behavior of an economy.

4. Results and discussion

a) **Results for the graphical evidence for Mexico**

The Great Recession of 2007-2009 was declared by the NBER began in December 2007 (Buckles *et al*, 2007). Therefore, and according to Buckles *et al* 2018, it is expected to see a decline in the number of births months before this date.

Graph 1 shows both time series (number of births and IGAE) and it is possible to see that two months before December 2007, the number of births had a decline. It changed the trend of the series and even though it presented a little recover for February 2008, this downward trend continued and increased its fall in November 2008 almost at the same time that IGAE presented an abrupt fall. As we said before, in the case of Mexico, the most dramatic falls in the number of births and IGAE is present at the same time (October 2008) due to the fact that a birth is the result of nine months of gestation, therefore we can assume that families perceived an adverse economic environment before the crisis was declared. The previous support the results in Buckles *et al* 2018, (with its proper considerations about the differences between total fertility and number of births) in which it is possible to see a fall in the fertility rates, quarters before the beginning of the crisis.

The CCI is an indicator that shows how optimistic are the consumers in relation to the general performance of the economy and how they feel about their financial perspectives for the future. This indicator is important for our study because the consumers could perceive negative conditions that could affect their life-long decisions, related to their aims of having a baby.

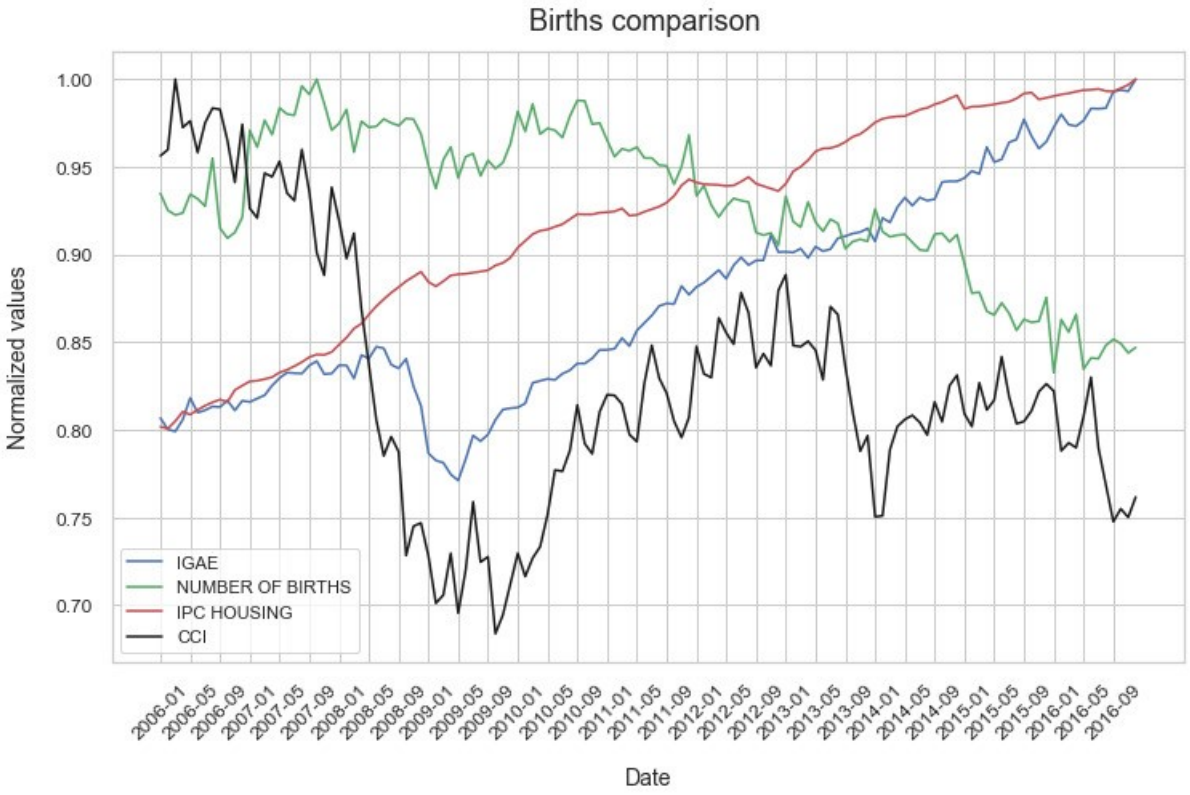
Graphic 1 shows the behavior of both time series (number of births and ICC) and it is possible to appreciate that the CCI presents a decline in August 2007 (four months before the official beginning of the crisis) and the number of births shows its fall in October 2007, but again, a birth it is the result of a period of nine months of gestation. Therefore, we can say that the abrupt fall in the number of births is the result of the perception of problems for a period of at least nine months. We could have seen the decline in the birth series a couple of months before as in Buckles *et al* (2018).

These results support the Malthus theory that stated that an increase in the income would cause an increase in fertility due to the families (Becker, 1960) have a more positive perspective about their future income, therefore, they will not postpone the decision of having a baby.

The nature of the Great Recession of 2007-2009 is strongly related to the real estate sector. The expansionist policies (specifically low-interest rates) of the U.S. the years before the crisis, eased a great number of consumers to purchase a house despite their low credit quality. The interest rates let them buy a property regardless of their capacity to pay for it. A great number of loans were granted at high-interest rates because of the risk they represented. These credits were known as *subprime*. These conditions created a bubble that began to be untenable in the middle of 2006, due to an increase in the prices of some commodities and had a fatal end with the bankruptcy of some funds linked to the risky mortgages (Cruz-Aké *et al*, 2011). The growth in the offer of properties caused that the prices of the real estate sector fell and the promise of can be able to sell their house at a higher price than they paid (if they were not capable to pay for it), caused a decline in the prices and a great number of credit holders lost their heritage.

Graphic 1 shows an increasing trend in the IPC Housing series but we are still able to identify a fall in the trend of the time series in December 2008. For the time series number of births, is clear that the respective fall happened at the same time, but again, is clear that birth is a result of nine months of gestation and the previous months to take the decision.

For these variables, it is clear that when the IPC Housing had a recovery a year after the fall, the number of births continued falling during the crisis and it did not recover its past positive trend until January 2010, supporting the hypothesis in Buckles *et al* (2018) that stated that the number of conceptions has a slow recovery after a crisis.



Graph 1. IGAE, number of births, IPC Housing and CCI time series from January 2006 to December 2016.
Source: with data from INEGI

5. Results of for the Granger Causality Analysis

Table 1 presents the sample size, the optimal lags and the results for the Wald test performed for significant and nonsignificant variables for each country. KPSS test and others are available upon request due to space reasons. It is important to remark that for Mexico the frequency data is monthly while for the other economies it has a quarterly frequency.

Table 1. VAR and VEC calibration. Abbreviations. CCI: Consumer Confidence Index, UNE: unemployment, HOU: housing, IR: interest rate GDP: Gross Domestic Product, MAR: marriages, ER: exchange rate.

COUNTRY	PERIOD	SAMPLE SIZE	OPTIMAL LAGS	ENDOGENOUS VARIABLES	EXOGENOUS VARIABLES	NON SIGNIFICANT VARIABLES
MEXICO[5]	1M2006-12M2016	132	13	Births[6], CCI[6], UNE[6]	HOU[6], IR[7]	GDP[6], MAR[6] ER[7]
GERMANY[8]	1Q1999-4Q2016	72	2	Births[9], GDP[10], UNE[11]	IR[10]	MAR[9], CCI,[11] HOU[11] ER[10]
CHILE[8]	1Q2005-4Q2016	48	3	Births[12], CCI[11], UNE[11], IR[13], GDP[10]	HOU[11], MAR[14]	ER[13]
SINGAPORE[8]	1Q2000-1Q2018	74	4	Births[15], HOU[10] MAR[15]	—	UNE[15], GDP[15], ER[16]
SOUTH AFRICA[8]	1Q2006-1Q2016	44	2	Births[17], ER[10], CCI[11], HOU[11], GDP[10]	—	MAR[17], IR, UNE[11]

Source: own elaboration with E-Views9.

[5]Monthly data [6]Source: Instituto Nacional de Estadística y Geografía (`www.inegi.org.mx`) [7]Source: Banco de México (`www.banxico.org.mx/`) [8]Quarterly data [9]Source: Statistisches Bundesamt (`www.destatis.de/`) [10]Source: Saint Louis Federal Reserve (`https://fred.stlouisfed.org/`) [11]Source: Organization for Economic Cooperation and Development (`www.oecd.org`) [12]Source: United Nations Statistics Division (`www.data.un.org`) [13]Source: Banco Central de Chile (`www.bcentral.cl`) [14]Source: Instituto Nacional de Estadísticas (`www.ine.cl`) [15]Source: Department of Statistics Singapore (`www.gov.sg`) [16]Source: Moneraty Authority of Singapore (`www.mas.gov.sg`) [17]Source: Statistics Shouth Africa (`www.statssa.ov.za/`)

Table 2 presents the results of the Granger Causality test for the VAR models and Table 3 presents the results for the VEC models for all countries.

a) **Results for Mexico**

The Granger causality test for the VAR model showed a causal relationship between unemployment and the number of births in both ways. It supports conclusions from Currie & Schwandt (2014), Andersen & Ozcan (2011), Buckles *et al*, (2018), Bellido & Marcén (2019) and Seltzer (2019). The ICC did not reveal a causal relationship to the number of births.

The Granger causality test for the VEC model revealed a causal relationship from unemployment to the number of births. In this case, the IPC Housing also showed a causal relationship to the number of births. Similar results were captured in the graphical evidence section in this study and in Buckles *et al* (2018) and Shneider (2015), who found that fertility declines with the consumer confidence. All the variables together (IPC Housing, unemployment, TIIE, and ICC) also showed a causal relation as a set, a result not captured before for any other study.

b) **Results for Germany**

The Granger causality test for the VAR model revealed that there is no causal relationship from GDP and unemployment to the number of births individually or as a set.

After the elaboration of a VEC model, we found that that the number of births could be explained by all the other variables as a set, and individually, by the prices of housing and by the number of marriages. This last relation is in both ways. It seems that the decision of having a baby in Germany is more reasonable as people look more interested in economic variables and a stable environment to take the decision.

c) **Results for Chile**

The Granger causality test for the VAR showed that there is not a causal relation from any of the variables to the number of births, individually or as a set, but the number of births presents a causal relation to the

CCI and the unemployment. The causal relation between the number of births and unemployment could be explained by educational factors where a woman prefers to raise her family instead of having a job or due to the deficient maternity leaving policies or the lack of day care centers.

For the case of the VEC model it was found that there is an individual causal relation from the confidence index, the number of marriages and the exchange rate to the number of births. The causal relation is present from all the variables as a set. The number of births has a causal relation to unemployment.

Chile seems to be another country where people are interested in ensuring stable economic conditions before to take the decision of having a baby, being CCI a factor to consider, supporting Shneider (2015). There is no previous evidence of relation from the exchange rate to the number of births.

d) **Results for Singapore**

There was not a CCI reliable source, therefore, for this country, it is not included. Despite the lack of a variable, the elaborated model did not present unit root and the residuals showed serial correlation, avoiding the problem of an omitted variable.

The Granger causality test for the VAR model showed that marriages have a causal relation explaining the number of births. Marriages and housing as a set have a causal relationship to the number of births, and the number of births has a causal relation to marriages. Singapore seems to be a more traditional country where marriage is still important to take the decision of having a baby. Religious reasons could be a factor behind it and the desire of having a heritage for the families result important.

After the elaboration of the VEC model, we found that the number of births could not be explained by any of the variables individually or as a set, but the number of births could explain the number of marriages in a long term. The relation between marriages and the number of births also appears in the long term.

e) **Results for South Africa**

The Granger causality test for the VAR model revealed that exists a causal relationship between the exchange rate and the number of births and from the GDP to the number of births. The whole set of endogenous variables has a causal relation to the number of births, revealing the interest of people of the general economic performance instead of the individual variables.

The VEC model showed a causal relation from the house prices to the number of births. The set of variables also showed a causal relationship to the number of births for the long term, showing that in the long term the whole set of variables are relevant.

Table 2. Results for the Granger Causality Test for the VAR models

VAR GRANGER CAUSALITY/BLOCK EXOGENITY WALD TEST

H_o : There is not causality

COUNTRY: MEXICO

Dependent variable: Number of births

Excluded	Chi sq	df	Prob.
CCI	7.813	13	0.8556
Unemployment	33.9438	13	0.0012
All	55.9132	26	0.0006

Dependent variable: Unemployment

Excluded	Chi sq	df	Prob.
Births	35.458	13	0.0007
CCI	14.2772	13	0.3546
All	61.3164	26	0.0001

COUNTRY: CHILE

Dependent variable: Number of births

Excluded	Chi sq	df	Prob.
CCI	7.39	3	0.0605
Unemployment	4.6535	3	0.199
Interest Rate	0.2897	3	0.962
GDP	2.8068	3	0.4224
All	20.8633	12	0.0524

Dependent variable: CCI

Excluded	Chi sq	df	Prob.
Unemployment	5.4561	3	0.1413
Interest Rate	3.015	3	0.3893
Births	10.572	3	0.0143
GDP	3.1003	3	0.3764
All	19.9513	12	0.068

Dependent variable: Unemployment

Excluded	Chi-sq	df	Prob.
CCI	8.3996	3	0.0384
Interest Rate	3.1762	3	0.3652
Births	24.2776	3	0
GDP	7.4915	3	0.0578
All	63.8011	12	0

COUNTRY: GERMANY

Dependent variable: Number of births

Excluded	Chi sq	df	Prob.
GDP	2.9198	2	0.2323
	3.8153	2	0.1484
All	4.3569	4	0.3599

COUNTRY: SINGAPORE

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
Housing	7.5527	4	0.1094
Marriages	18.9668	4	0.0008
All	40.9397	8	0

Dependent variable: Housing

Excluded	Chi-sq	df	Prob.
Births	4.5268	4	0.3394
Marriages	8.5906	4	0.0722
All	13.6909	8	0.0902

Dependent variable: Marriages

Excluded	Chi-sq	df	Prob.
Housing	20.4339	4	0.0004
Births	14.4662	4	0.0059
All	35.5826	8	0

COUNTRY: SOUTH AFRICA

Dependent variable: Number of Births

Excluded	Chi-sq	df	Prob.
CCI	2.4928	2	0.2875
Housing	3.229	2	0.199
GDP	6.0031	2	0.0497
Exchange Rate	7.4467	2	0.0242
All	29.2832	8	0.0003

Source: own elaboration with E-Views9

Table 3. Results for the Granger Causality Test for the VEC models

VEC Granger Causality/Block Exogeneity Wald Tests

Country: Mexico

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
Unemployment	24.52463	12	0.0172
CCI	11.94151	12	0.4504
IGAE	13.50274	12	0.3336
IPC Housing	14.59866	12	0.2641
Exchange Rate	14.50703	12	0.2695
TIIE	11.31941	12	0.5018
Marriages	15.80657	12	0.2003
All	114.2521	84	0.0157

Country: Germany

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
CCI	3.868807	3	0.276
Unemployment	4.743866	3	0.1915
Housing	14.37491	3	0.0024
Interest rate	4.646641	3	0.1996
Marriages	32.12842	3	0
GDP	4.671733	3	0.1975
Exchange Rate	0.203616	3	0.977
All	120.4529	21	0

Dependent variable: Housing

Excluded	Chi-sq	df	Prob.
CCI	0.357774	3	0.9488
Unemployment	2.057802	3	0.5605
Interest Rate	0.892172	3	0.8273
Marriages	15.58692	3	0.0014
Number of Births	10.66256	3	0.0137
GDP	3.679083	3	0.2983
Exchange Rate	0.055219	3	0.9966
All	25.93748	21	0.2088

Country: South Africa

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
CCI	3.826776	2	0.1476
Unemployment	4.816439	2	0.09
Housing	6.238688	2	0.0442
Interest rate	4.115934	2	0.1277
Marriages	3.144149	2	0.2076
GDP	2.815184	2	0.2447
Exchange rate	3.905352	2	0.1419
All	38.16482	14	0.0005

Country: Chile

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
CCI	11.18586	3	0.0108
Unemployment	2.634946	3	0.4514
Housing	2.831318	3	0.4184
Interest Rate	4.7761	3	0.1889
Marriages	18.45861	3	0.0004
GDP	6.059365	3	0.1088
Exchange Rate	9.62919	3	0.022
All	35.61293	21	0.0242

Dependent variable: Unemployment

Excluded	Chi-sq	df	Prob.
CCI	6.048302	3	0.1093
Housing	7.647812	3	0.0539
Interest Rate	8.954831	3	0.0299
Marriages	7.607323	3	0.0549
Number of births	22.24062	3	0.0001
GDP	9.454478	3	0.0238
Exchange rate	0.893691	3	0.827
All	149.8801	21	0

Country: Singapore

Dependent variable: Number of births

Excluded	Chi-sq	df	Prob.
Unemployment	2.303539	2	0.3161
Housing	0.877581	2	0.6448
Interest rate	0.19976	2	0.9049
Marriages	1.099302	2	0.5772
GDP	2.130256	2	0.3447
Exchange rate	0.424638	2	0.8087
All	7.758269	12	0.8037

Dependent variable: Marriages

Excluded	Chi-sq	df	Prob.
Unemployment	0.51853	2	0.7716
Housing	12.27894	2	0.0022
Interest rate	0.604732	2	0.7391
Number of births	6.767615	2	0.0339
GDP	2.254135	2	0.324
Exchange rate	3.631438	2	0.1627
All	25.0905	12	0.0144

Source: own elaboration with E-Views9

6. Results for the phase synchronization

Now, it is compared to the results for the Granger Causality approach using the phase synchronization. It is supposed that causal relationships showed in the VAR and VEC models will be also present in synchronized periods or a forward-looking behavior from some of the variables to others. It will also help to state the forward-looking behavior present in the case of Mexico and to determine with this approach if in other countries the behavior is the same. Table 4 presents the filtering level for each variable for each country and the number of cycles present in each variable.

The results for the phase differentials for all studied economies are presented in Figures 1 to 5, which shows all the synchronized periods for each compared variable. Periods with perfect phase synchronization are marked in dark grey while weak synchronization periods are marked in light grey. Variables without periods of synchronization were omitted because of space reasons.

Table 4. Filtering level and number of cycles by country

COUNTRY: MEXICO			
VARIABLE	**FILTER**	**NUMBER OF CYCLES**	**NUMBER OF CYCLES (BIRTHS)**
MARRIAGES	0.6	19	19
IGAE	0.6	7	19
IPC HOUSING	0.7	10	16
UNEMPLOYMENT	0.6	19	18
TIIE	0.6	5	19
EXCHANGE RATE	0.7	10	16
CCI	0.7	15	16

COUNTRY: GERMANY			
VARIABLE	FILTER	NUMBER OF CYCLES	NUMBER OF CYCLES (BIRTHS)
MARRIAGES	0.8	7	7
GDP	0.7	2	4
HOUSING	0.7	5	4
UNEMPLOYMENT	0.75	2	5
INTEREST RATE	0.7	3	4
EXCHANGE RATE	0.6	8	6
CCI	0.6	7	6

COUNTRY: CHILE			
VARIABLE	FILTER	NUMBER OF CYCLES	NUMBER OF CYCLES (BIRTHS)
MARRIAGES	0.68	6	3
GDP	0.65	1	3
HOUSING	0.68	1	3
UNEMPLOYMENT	0.68	6	3
INTEREST RATE	0.73	2	3
EXCHANGE RATE	0.68	4	3
CCI	0.73	3	3

COUNTRY: SINGAPORE			
VARIABLE	**FILTER**	**NUMBER OF CYCLES**	**NUMBER OF CYCLES (BIRTHS)**
MARRIAGES	0.68	10	10
GDP	0.68	1	10
HOUSING	0.65	4	11
UNEMPLOYMENT	0.6	8	10
INTEREST RATE	0.6	3	10
EXCHANGE RATE	0.5	7	10

COUNTRY: SOUTH AFRICA			
VARIABLE	FILTER	NUMBER OF CYCLES	NUMBER OF CYCLES (BIRTHS)
MARRIAGES	0.75	4	4
GDP	0.5	2	7
HOUSING	0.5	1	4
UNEMPLOYMENT	0.78	3	4
INTEREST RATE	0.7	1	4
EXCHANGE RATE	0.45	3	6
CCI	0.78	2	3

a) **Results for Mexico**

Unemployment presented four periods of synchronization which confirms the relationship found with the VAR and VEC models and the affirmation in Currie & Schwandt (2014), Andersen & Ozcan (2011) and D'Addio & d'Ercole (2005). The VEC model could find long term relationships which also appeared with the phase synchronization, which lead to establishing that the relationships are non-linear and long term.

The absence of synchronization during the period of the 2007-2009 crisis is relevant due to the fact that it is a similar result as in Calderón-Villarreal *et al* (2017) who find the loss of synchronization during periods of crisis. Unemployment and marriages presented synchronization during that period but just for 2 months for both cases. For the case of unemployment, it also appeared in the VEC model. CCI also presented a period of perfect synchronization from October 2007 to January 2008.

It is important to highlight the absence of synchronization between marriages and the number of births,

representing a reality in which marriage is not the only option for raising a family. The prices in properties were the variable with most synchronized periods converting it into a variable relevant for family decisions and confirming the nature of the Great Recession of 2007-2009.

b) **Results for Germany**
The relationship found with the VEC model between the number of births and marriages is not present with the phase synchronization, but the variable housing presented two periods of synchronization: from 2008Q2 to 2008Q3 and a long one from 2011Q2 to 2013 Q2, representing the aim of the parents for have their own houses before taking a decision about fertility turning it into a rational decision as in Davia & Legazpe (2013).

Once again it is important to highlight the absence of synchronization for the variables during the *subprime* crisis, even when variables like exchange rate and CCI presented synchronization before the crisis, it seems to lose the synchronization during crisis periods, remarking the importance previously stated by Muradoglu *et al* (2000) and Schneider (2015).

c) **Results for Chile**
For Chile, the relationship found with the VAR and VEC models between the CCI and the number of births is also present with the phase synchronization with the period of phase synchronization present from 2007Q2 to 2009Q4 and during the two first quarters of 2011 and confirming the relationship in Schneider (2015).

Marriages also presented a synchronized behavior from 2008Q3 to 2009Q4 and from 2011Q2 to 2011Q4. This relationship is also present in the VEC model. Exchange rate presented a synchronized behavior from 2012Q3 to 2015Q1, confirming the causal relationship found the VEC model. Interest rate presented a period of synchronization from 2009Q1 to 2009Q4 remarking the relation established by Murgadoglu *et al* (2000).

The results for Chile are interesting because the synchronized period corresponds to the *subprime* crisis for the variables marriages, interest rate and CCI, which is contrary to the findings for Mexico and Germany, where the variables did not present synchronization during the crisis. It maybe represents that the importance of these variables is only relevant for chilean families during periods of crisis when having a baby requires a more planned decision.

d) **Results for Singapore**
The results for Singapore confirm the relationship found with VAR model between the number of births and marriages, being that these two variables presented a period of synchronization from 2010Q2 to 2014Q1 and a short one during the first two quarters of 2007 confirming that for families in Singapore marriage is still relevant for making decisions about having a baby.

It is interesting that the variables housing, unemployment, interest rate, and exchange rate presented important periods of synchronization, but only housing and interest rate presented two quarters of synchronization during the 2007-2009 crisis. The synchronization for these variables is present again after the crisis for long periods, confirming the loss of synchronization during crisis periods as in Calderón-Villarreal *et al* (2017). Synchronization for marriages, housing, unemployment, interest rate, and the exchange rate was present basically for the same quarters.

e) **Results for South Africa**
For South Africa, there are periods synchronized in phase for the exchange rate (as with VAR model) and

housing (as with VEC model). The relation present with GDP is not present with the phase synchronization technique.

Marriages, housing, and interest rate shared a period of synchronization from 2006Q4 to 2009Q1, but it was lost when the effects of the Great Recession were deeper. Short periods of synchronization are common for housing, interest rate, exchange rate, and unemployment, confirming the importance as in Murgadoglu (2000) and Lovenheim & Mumford (2013).

In general, for all studied economies it is important to highlight the fact that the compared variables lost synchronization during the 2007-2009 crisis., or in its case, presented periods were short. For South Africa, marriages, housing, and interest rate were the only variables with a significant period of synchronization during that crisis. The synchronization present in Chile during the crisis was a weak one. These results are similar to the findings in Cladерón-Villarreal (2017) for periods of crisis.

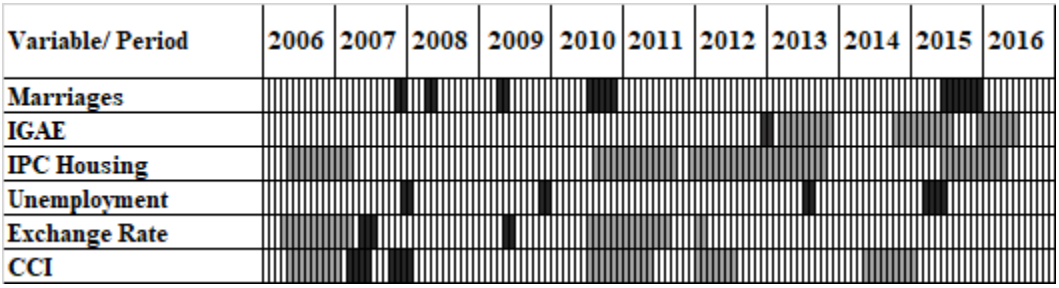


Figure 1. Synchronized periods for Mexico

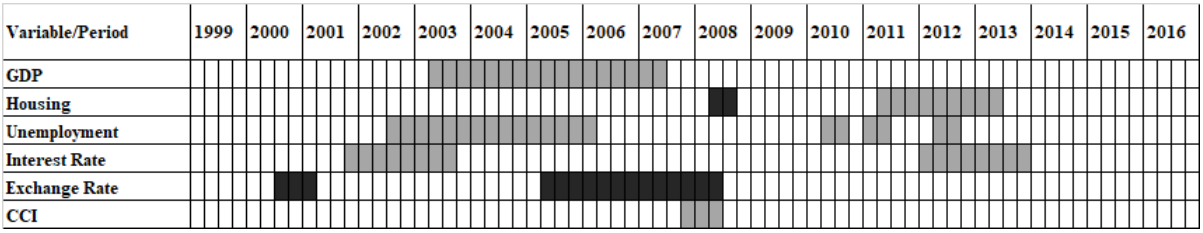


Figure 2. Synchronized periods for Germany

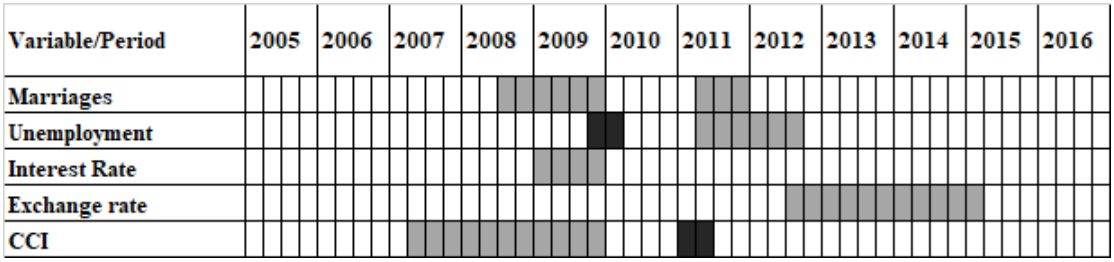


Figure 3. Synchronized periods for Chile

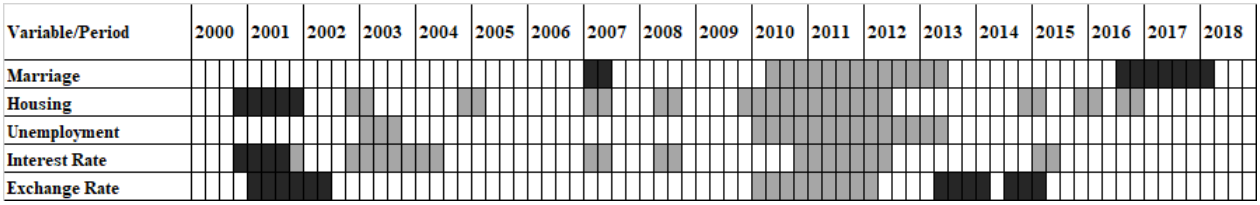


Figure 4. Synchronized periods for Singapore

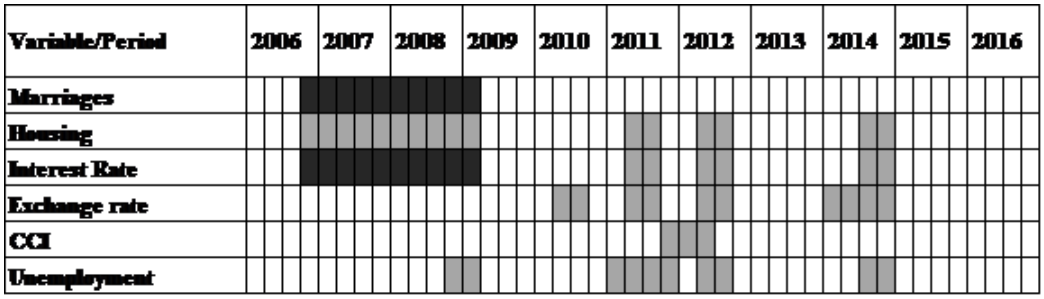
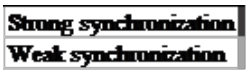


Figure 5. Synchronized periods for South Africa



7. Conclusions

The objective of this paper is to prove that the number of births is a variable to watch as a crisis indicator and not just a response variable. For the study, it was used simple graphical evidence, Granger causality, and phase synchronization.

It was used the variable number of births for simple graphical evidence in the behavior prior to the *subprime* crisis for the case of Mexico. Our results support the showed by the annual and quarterly evidence in the study performed by Buckles *et al* (2018) when they proved that a fall in the growth rate of fertility preceded the last three crises declared by the NBER. Our results are similar despite the frequency of the data and support the conclusion in Verdickt (2019) which also states that fertility is a leading indicator for recessions.

The simple graphical evidence, showed the same pattern present in the original study: a forward-looking behavior of the number of births regarding the IGAE, the CCI, and the housing prices index, but we need to take in consideration that the number of conceptions is not available, therefore, as we expected, the declines in the number of births appears at the same time that the falls in the other studied indicators. The prior totally supports the study of Buckles *et al* (2018) and Verdickt (2019), stating the forward-looking behavior of the fertility and not just as a responding variable to economic factors.

For the Granger causality analysis and the non-parametric approaches, we got mixed results for some of the studied countries, but in general, we can say that the number of births has an anticipated behavior regarding important economic variables. The number of births is a driving factor to increase GDP due to the need for the labor force as Malthus (Mellos, 1988) and Becker (1960) previously established.

The Granger causality tests showed linear relations, being the most important that one present between the marriages and the number of births. An also important one was the relationship present in the number

of births causing unemployment in Chile, South Africa, and México. It is supposed that it is due to the positive causal effect between unemployment and the timing of the first births in women found by Andersen & Ozcan (2011). It is also supposed that it could be due to weak maternity policies in no completely developed countries, being this a new research line for the future.

The phase synchronization showed that the relation between the number of births and the other economic variables is not a linear one. It means that the variables are not related in a normal or linear way.

It is also remarkable the fact that most of the compared variables lost synchronization before or during crisis periods as the results presented in Calderón-Villarreal *et al* (2017). Remaining synchronized periods presented a strong synchronization for the cases of Singapore (during the *Dotcom* crisis) and South Africa and Germany (during the *subprime* crisis). Strong synchronized periods are not present again after the crises, supporting the affirmation that fertility has a slow recovery which has an effect that lasts for generations made by Buckles *et al* (2018) and Sawhill & Guyot (2019) who explain the decline in the fertility rates by some factors that include the exposition to the effects of the Great Recession of specific cohorts.

The link between marriages and the number of births seems to be broken but both, the number of births and marriages continue to push the GDP, i.e., marriage means not the only option for maternity (Schneider, 2015) and its final propose has become not only procreation but it is an important factor that could boost housing prices due to the fact that a couple needs a place to raise a family.

Future research could focus on the reasons which explain the variables synchronization during crisis periods and to replicate this study for other economies as the data is available. Other researchers could focus on other demographic variables as divorces and suicides and their relationship with macroeconomic variables.

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