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Mexico and the United States: cycle synchronization, 1980.1-2013.4

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All the investigators cherish the same ultimate aim –namely to attain better understanding of the recurrent fluctuations in economic fortune that modern nations experience… The way we have chosen is to observe the business cycles of history as closely and systematically as we can.
Burns and Mitchell (1946)

Abstract

We estimated the progressive, structural synchronization of the Mexican growth cycle with that of the US (total and industrial) for 1980.1-2013.4. By applying the Quandt-Andrews (1993) and Bai-Perron (2003) unknown-breakpoint tests, we identified that before 1994.4 there was no statistically significant relationship between the Mexican GDP growth cycle and the US industrial output cycle, but a weak (statistically significant) relationship with total US GDP cycle. However, since 1997.4 and particularly since 2001.2, there is a vast and increasing synchronization and determination from the US industrial cycle to the Mexican cycle ($R^2 = 0.96$). The degrees of freedom of Mexican domestic economic policy have thus drastically decreased.

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***JEL Classification*:** C24; F15; F62.
***Keywords*:** Mexico-US growth cycles, synchronization, end-of-sample correction, unknown-breakpoint tests (Quandt-Andrews, 1993 and Bai-Perron, 2003).

Resumen

Estimamos la sincronización estructural y progresiva de los ciclos de crecimiento de México y Estados Unidos (total e industrial) del primer trimestre de 1980 al cuarto trimestre de 2013. Aplicando las pruebas de cambio estructural desconocido de Quandt-Andrews (1993) y Bai-Perron (2003), identificamos que antes del cuarto trimestre de 1994 no había sincronización estadísticamente significativa entre el PIB de México y el del producto industrial de los Estados Unidos; pero una relación débil (estadísticamente significativa) con el PIB total de Estados Unidos. Sin embargo, desde el cuarto trimestre de 1997 y, particularmente, desde el segundo trimestre de 2001 la sincronización es alta y creciente desde el ciclo del producto industrial de Estados Unidos hacia el ciclo de México (R^2 = 0.96). Esto significa que los grados de libertad de la política económica interna han decrecido notablemente.

***Clasificación JEL*:** C24; F15; F62.
***Palabras Clave*:** ciclos de crecimiento de México – Estados Unidos, sincronización, corrección al final de la muestra, pruebas de cambio estructural múltiple con fecha desconocida (Quandt-Andrews, 1993 y Bai-Perron, 2003).

Introduction

Mexico has experienced deep economic changes since 1985. One of them was the trade liberalization process and the country’s integration to globalization. On January 1st, 1994, when the North American Free Trade Agreement (NAFTA) came into force, the Mexican economy was quickly incorporated into the United States’ (US) industrial production process and, thus, transformed itself from a closed economy to one that is integrated to the rest of the world, in particular to the US economy.

Trade liberalization began with the unilateral decision of the Mexican government to dismantle the trade protection apparatus by entering into the General Agreement on Tariffs and Trade (GATT) in 1986, and the subsequent signing of NAFTA. This process generated profound and relevant changes in the internal structure of the Mexican economy.

The integration ultimately brought a significant increase in the volume of trade and the growth cycle convergence to US industry. These two conditions shifted the Mexican growth engine to its export manufacturing sector, and de facto replaced the old engine for economic growth based on public investment within a protected domestic market. This resulted in a gradual synchronization of the Mexican growth cycle with the US industrial growth cycle.

The aim of this paper is to calculate the growth cycles of Mexico's GDP and US total and industrial output in order, and thereby demonstrate that there has been a progressive (i.e. dynamic) synchronization process of Mexico's GDP growth cycle to the US's industrial output since 1995. It is not the aim of this article to probe deeper into the numerous implications of this phenomenon, but rather to analyze a process that has been dynamic in nature. A key insight obtained is that the Mexican economic cycle depends an estimated 96% on the US industrial growth cycle, which suggests that there is very little leeway for domestic policy to influence this important variable, and sets this article apart from most of the related literature.

By applying the X12-ARIMA filter, the St-Amant and van Norden (1997) end-of-sample-correction procedure and a $\lambda = 1{,}096$ for the HP filter for Mexico, as proposed by Sarabia (2010), we were able to calculate rigorously the cyclical component of GDP in both countries. We proved Granger causality that runs from the US total and industrial output cycles to the Mexican GDP cycle, and by applying the Quandt-Andrews (1993) and Bai-Perron (2003) unknown-breakpoint tests we estimated endogenously and measured the synchronization process. We used the modern growth cycle approach by Lucas (1977).

The synchronization of the cycles is evidence of a progressive process of economic integration, brought about deliberately by Mexican authorities in their search for a new engine of growth, and also as part of the incorporation of Mexican industries into the value chain of the US economy. All of these processes have evolved with great intensity since the second half of the 1990s, and it is reasonable to speculate that the synchronization has undergone different stages, responding to the dynamics of the integration as such, but also to the various stances adopted by the Mexican economic authorities over the years.

Arriving at the conclusion that the observed synchronization has been a consequence of economic integration and, furthermore, that it has been progressive, required an econometric tool which differs from the technique that is ordinarily applied. The approach presented in this article allows for an accurate characterization of this profoundly dynamic process, leading to an evaluation of the progressive nature of the synchronization of the cycles. Therein lies the main contribution of this text, and also the key feature that sets it apart from most of the related literature.

With these objectives in mind, a synchronization parameter was recursively estimated. The parameter is ordinal in nature and indicates the relative intensity of the synchronization, based on Quandt-Andrews (1993) and Bai-Perron (2003) structural-change tests, which calculate endogenously the evolution of this important measure.

Section 1 reviews the literature about the economic integration of the Mexican economy to the US and locates our contribution. Section 2 presents the economics of synchronization. Section 3 presents the econometric issues and discusses the convenience of the HP filter to identify the growth cycles. In Section 4 we discuss the main empirical results. The last section concludes.

1. Literature review

There is a general consensus in the literature supporting the existence of a significant synchronization between the cycles and/or the growth of the economies of Mexico and the United States.

With the exception of Herrera (2004) and Mejía, Gutiérrez and Farias (2006b), who do not investigate the synchronization of the cycles but rather the presence of common trends with cointegration, partial correlation methods are predominant in the study of cycle synchronization. This has been the basis for research in comovement, determining the existence or absence of synchronization between the cycles of sectors and/or countries. Primary efforts are usually directed towards analyzing the presence of three distinct types of partial correlation: a) negative synchronization, $r_{i,j} < 0$; b) positive synchronization, $r_{i,j} > 0$, and c) absence of synchronization, $r_{i,j} = 0$. However, this type of analysis is static in that it neither studies nor measures whether the relationship has evolved over time, or whether the direction of causality has changed; this is due to the fact that the entire period of interest is analyzed jointly[1], which yields only one partial correlation coefficient.

[1] According to Mejía *et al* (2006b), it is customary to consider a five-year period, leaving the choice of period length up to the researchers' best judgment. Our analysis relies on the search for structural changes using structural-break tests, a more robust methodology in that it avoids imposing synchronization periods exogenously.

In that sense, Torres and Vela (2003) ─through comovement analysis─ identified a relationship between the Mexican and the US business cycles to study regional integration implications (1991-2001). They found that the manufacturing sectors of both economies were highly integrated, so US industrial fluctuations affected the demand for Mexican exports and, in turn, these influenced the Mexican business cycle. They reported that Mexican exports and imports have converged as a result of the business cycle synchronization of both countries, which in turn has reduced the trade balance volatility. The authors further state that this synchronization has stabilized Mexican trade through the balancing of fluctuations in exports and imports. This has brought about a reduction of volatility in trade[2].

Chiquiar and Ramos-Francia (2005) present evidence that the economic links between Mexico and the United States were strengthened by NAFTA, due to the positive effect of commerce on the synchronization of the cycles.

Castillo, Díaz and Fragoso (2004) made a comparison for each manufacturing division in Mexico and the US (1980-2007) and found that it was unlikely that the synchronization of business cycles between these two countries has emerged only in manufacturing. Thus, they included the dynamics of services and aggregate consumption in the process. They applied the Johansen cointegration procedure to demonstrate that these variables shared common trends and cycles.

Herrera (2004) applied the econometric methodology proposed by Vahid and Engle (1993), and proved the existence of common trends and cycles between the Mexican and the US economies (1993-2001).

Mejía, Gutiérrez and Pérez (2006a), by applying the Kydland and Prescott (1990) methodology for quarterly data (1980.1-2004.1), analyzed the synchronization between the Mexican business cycle and some key variables of the external sector. Their results showed that those relationships were volatile during the 1980s. However, they found that the economic cycles of Mexico and the US have synchronized since the mid 90s, a phenomenon that is associated to economic liberalization and particularly to NAFTA.

Mejía *et al* (2006b) analyzed the degree of economic integration between Mexico and the US through the association between industrial and manufacturing sectors. To assess a long-term relation between Mexico's GDP and the US's, using annual data (1989-2002) they applied the Johansen

[2] As requested by a referee, this point has been particularly demonstrated for 2000-2012 in Section 2.

procedure and found that the series shared a common trend. They concluded that, because of NAFTA, both economies are highly synchronized.

Delajara (2012) analyses the synchronization of the economic cycle of various regions of Mexico with that of the US. The author's empirical analysis is carried out with a linear, structural time series model as framework, and finds that the covariance between cyclical disturbances in the US and the Mexican regions under consideration has a regional pattern, with higher covariance for the northern regions than for central and southern provinces.

Mejía and Erquizio (2013) analyzed and measured the effects of the most recent international economic cycle (2007-2009) on output and employment in Mexico and in the State of Mexico. Using quarterly and monthly data (2007-2010), they found that trade is the most important transmission mechanism.

This article updates the analysis on the matter (up to 2013.Q4) by using a different statistical methodology.

Parting from the notion that the synchronization of the cycles is a consequence of economic integration, we apply a statistical tool that allows for a dynamic, and thus more accurate portrayal of the synchronization process. The technique employed here differs from more common procedures in that it enables us to estimate periods of structural changes endogenously, which in turn support our finding that the synchronization process has been progressive. More specifically, this methodology enabled us to identify structural breaks, which reflect variations in the synchronization process. Consequently, we argue that the relationship has intensified progressively and significantly since the introduction of NAFTA in the 1990s. The endogenous structural-change-techniques applied here allow for a statistically rigorous measurement of specific stages. In that sense, our contribution is of a dynamic nature, unlike the aforementioned static approaches.

2. Synchronization factors

In Mexico, the liberalization and the globalization process[3] began with the entry into GATT in 1986. This process was eminently dynamic and eventually led to a synchronization to the US economy after NAFTA came into effect in 1994. The main objective was that, in the future, Mexican economic growth would depend on increasing production efficiency and

[3] Which reduced and eliminated tariffs and other non-tariff protectionist policies.

foreign investment. Serra (2008)[4] points out that the entry into GATT reallocated resources toward tradable sectors. It was the end of the import-substitution model that had been in effect in previous decades.

Kose, Meredith and Towe (2005) claim that, with this new economic model, Mexico found a new engine for economic growth by its insertion to the largest free market that had so far been built, NAFTA.

The structural crisis that began in 1982 –arising from the external debt crisis– represented the end of an economic model. Mexico entered then a long stagflation phase, which simultaneously generated enormous volatility in the main macroeconomic variables and caused a stark fall in expectations.

In this context, the new administration of Mexico (1988-1994) saw in NAFTA the potential for developing a new engine of growth or growth model; achieving a new industrialization process; broadening the range of available products in the country; increasing the consumer's surplus; and opening the economy to enhance competition and productivity and reduce prices. Additionally, the country sought to enter a new stage of macroeconomic stability by connecting itself to a strong and stable economy; boost savings and multiply its sources of financing for growth; increase foreign investment (both direct and portfolio) and domestic investment; and, lastly, have access to new technologies. Another equally important aspect is that the economic integration with the US could improve the functioning of Mexican institutions and generate new growth expectations. Taken together, these effects would result in better conditions for growth and economic development. This was the main objective of the integration.

Figure 1 clearly shows strong volume effects on trade from both commercial treaties. GATT, for example, increased the rate of trade openness despite the fact that Mexico stagnated between 1985 and 1989. NAFTA, meanwhile, provided new economic momentum since 1994. Trade openness reached its peak around the year 2000 as did GDP growth (6.6%). The 2001-2003 recession seriously affected trade openness. But thereafter, both variables recuperated.

Because of NAFTA, between 1993 and 2012 total exports and imports grew almost seven times over: from $117 billion dollars to more than $750 billion. About 90% of this flow was due to the US-Mexico trade.

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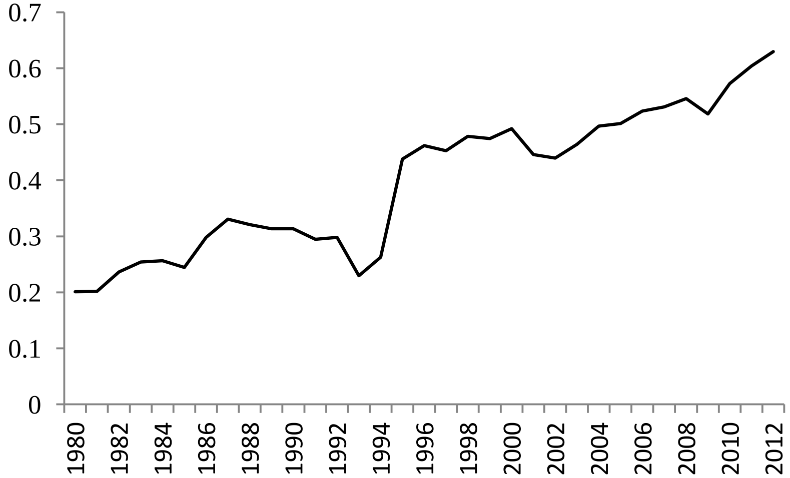
[4] Former Industry Secretary under Salinas administration (1988-1994).

Figure 1
Mexico: trade openness rate, 1980-2012



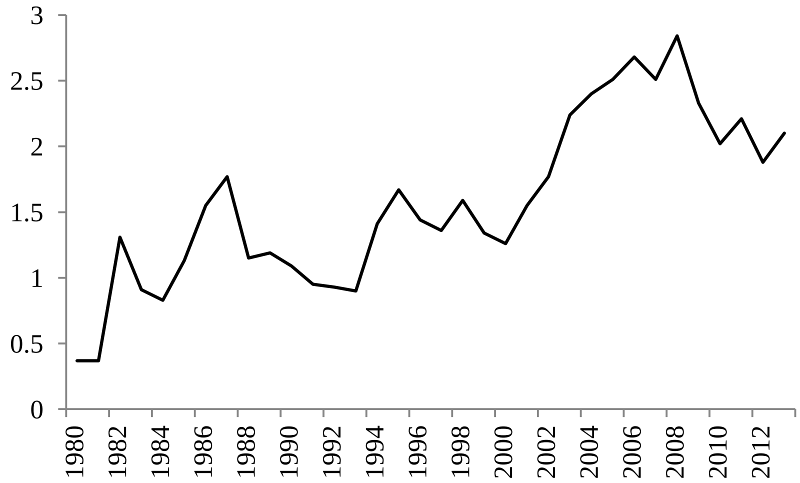
Note: trade openness rate = (exports + imports)/GDP.
Source: World Bank (2013).

Delgado (2009) and Portnoy (2003) highlighted the benefits that NAFTA represented for Mexico:

a) New markets for Mexican products and better conditions to attract domestic and foreign capital, because the trade agreement was expected to raise investment and domestic savings rates.
b) Relocation of labor intensive activities to Mexico, which would lead to job creation and wage increase. It was assumed that eventually the traditional wage gap would vanish (Loría, 2014).
c) Domestic consumers would benefit as they acquired goods and services at competitive prices.
d) Strengthening efficiency of domestic producers because of international competition.
e) NAFTA would facilitate the economic process and improve the institutional life in Mexico due the implementation of new and clear "rules of the game". That is, after several years of stagnation and political turmoil, the integration to the US would put the rule of law in action. The goal here was to strengthen the democratic transition by modernizing the Mexican society and making institutions more transparent (Loría, 2014).

Despite the absence of a labor mobility agreement within NAFTA, there has been a large, de facto migration to the US, which has generated nonnegligible remittances to many Mexican families as a source of income and consumption. This labor flow has linked labor market conditions in the US to consumption and savings in the Mexican economy (Figure 2)[5]. It's worth mentioning that this effect was the opposite to the objectives of the integration[6].

Figure 2
Remittances to Mexico, 1980-2013
(% GDP)



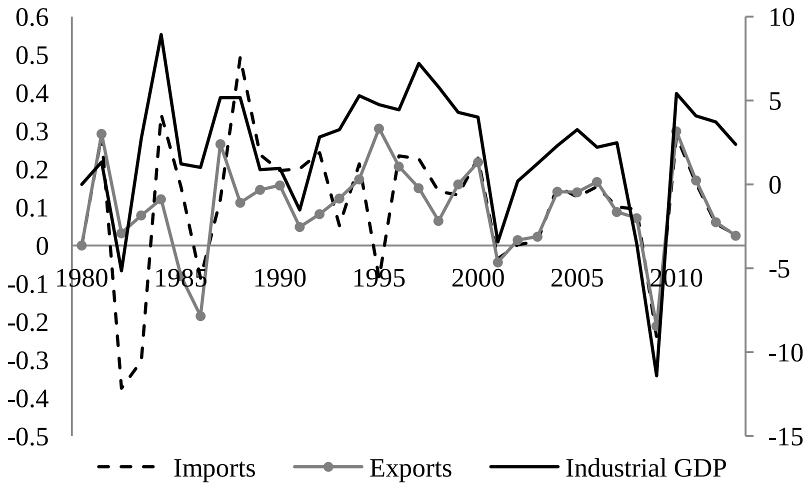
Source: Banxico (2014).

Another important effect of this economic integration is that the dynamics of Mexican imports and exports have coupled since 2000, as well as the growth of these variables and the growth of US industrial output (Figure 3)[7]. Thus, synchronization of the cycles and growth rates brought about a reduction of volatility, since the standard deviation of US growth is lower than it is

[5] It is precisely after 1994 that an exponential increase of migration to the United States began. The Mexican immigrant population in that country grew from 4 million in 1994 to 10 million in 2000, going from 10% to 22% of the total immigrant population of the United States (Migration Policy Institute, 2014).
[6] In words of the then president of Mexico, Carlos Salinas, at MIT in 1993: "NAFTA is an agreement of wage improvements… It is also an agreement for reducing migration, because Mexicans will no longer have to migrate north to find employment, they will now be able to find it in [my country]." (Loría, 2014).
[7] This last remark was prompted by a referee. It is worth highlighting that, since the year 2000, the partial correlation between growth in Mexican trade and in the US industrial product is 90%, with a correlation of 79% against total US GDP growth. Both correlations are significant at a 99% level.

Mexico. Between 1980 and 2000 the standard deviation of Mexican growth was 3.65, while that of the United States was[1] 1.8. Between 2000 and 2012 these were 2.9 and 1.7, respectively. However, it must be said that the volatility of industrial output increased from 3.1 to 4.6, which is likely a result of the relocation of activities to Mexico and also of the entering of China into the WTO, which had large deindustrializing effects for Mexico. These processes are also evident in the growth rates of Mexican GDP, US industrial output and US GDP, which were 2.7%, 3.1% and 3.3% for the period 1980-2000, and 2.2%, 0.47% and 1.6% for the period 2000-2012, respectively.

Figure 3
Rates of Growth



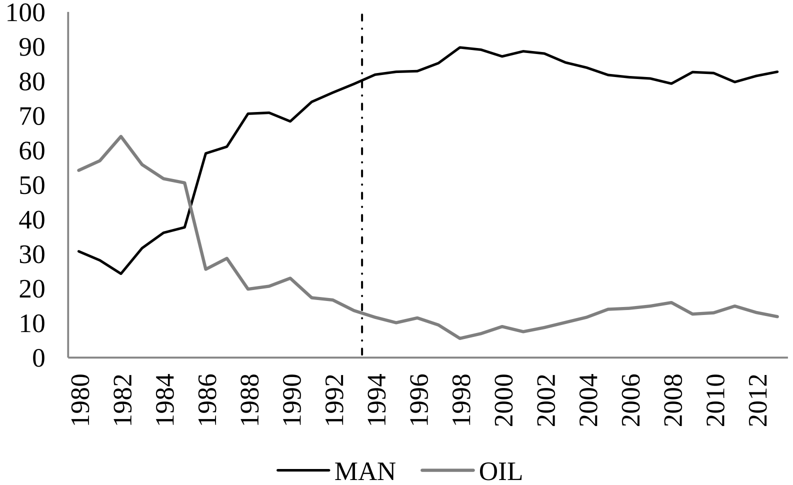
Source: own calculations based on: INEGI (2014) and FRED (2013).

The opening of the Mexican economy has been associated to a profound change in the composition of exports, to the extent that, in the mid-1980s, oil exports accounted for 57% of total exports, while manufacturing exports were only 40%. Currently, oil accounts for 16% and manufacturing 79% (Figure 4). This could be one of the most important outcomes of the economic integration: the new growth engine became manufacturing associated to the US industrial output. In other words, we can claim that the Mexican economy integrated into the US industrial production value chain.

[1] Although the term *Great Moderation* was coined later (Bernanke, 2004), to refer to the period of stabilization since the mid-1980s in the United States, it was thought that this effect would be transmitted to Mexico.

Figure 4

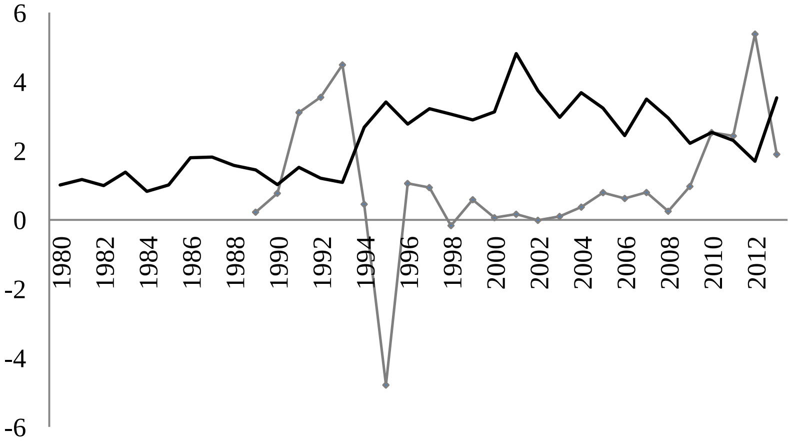
Oil Exports and Manufacturing Exports, 1980-2013
(% of total exports)



Source**:** Banxico (2014).

Figure 5

Foreign Direct Investment and Foreign Investment in Portfolio, 1980-2013,(% GDP)



Source: Banxico (2014).

Another synchronization factor to be acknowledged has to do with the intra-firm trade increase (Mejía *et al*, 2006a). Figure 5 shows that, since the second half of the 1980s, FDI grew rapidly and portfolio investment (FPI) did it as soon as the NAFTA negotiations started[2].

3. Econometric issues

3.1. Cycle estimation

X-12-ARIMA (U.S. CENSUS BUREAU, 2002) is a statistical method widely used, based on weighted moving averages, which explains the seasonal variation of a time series (Cortez, 2008 and Makridakis, Wheelwright and Hyndman, 2008). It has two[10] modules: the RegARIMA, which adjusts the series, and the X11 module, which decomposes the original series into trend-cycle, seasonal and irregular components.

In a strictly statistical sense (Enders, 2004), a time series (y_t) can be represented as follows:

$$y_t = y_t^{tr} + y_t^s + y_t^c + \varepsilon_t \tag{1}$$

Where the trend, y_t^{tr}, represents the underlying (secular) evolution of the time series; seasonality, y_t^s, reflects the periodic occurrence of phenomena in its evolution; cycle, y_t^c, represents periodic oscillations around the trend; and innovations, ε_t, are the erratic movements that do not follow a specific pattern. By definition, this component must be white noise.

Separating the trend and the cyclical components that the X-12 filter jointly estimates is necessary for the subsequent analysis.

In the literature, the HP filter (Hodrick and Prescott, 1997) has been very popular since its introduction, but very criticized as well[11].

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[2] It is not the goal of this article, but it is worth mentioning that this variable plummeted with the political crisis of 1993 and only recovered after the introduction of non-conventional monetary policy in 2009.

[10] RegARIMA models are ARIMA regression models, based on seasonal autoregressive integrated moving average (SARIMA) (Cortez, 2008; Makridakis *et al*, 2008).

[11] For ease of reading, we relegate to the statistical appendix a summary of these criticisms and of the procedures with which they were handled. A broad discussion of the criticisms and advantages of the HP filter versus other filters can be found in Loría and Salas (2014).

In order to deal with the end-of-the-sample problem[12], the St-Amant and van Norden (1997) procedure was applied to the conventional filter. Therefore, a new correction term that adjusted the estimation at the end-of-the-sample was introduced: $\sum_{t=T-j}^{T}(\Delta y_t^{tr} - u_{ss})$.

Therefore, the HP adjusted filter was defined as:

$$\min_{\{y_t^{tr}\}_{t=1}^{T}} \sum_{t=1}^{T}(y_t - y_t^{tr})^2 + \lambda \sum_{t=1}^{T-1}\left((y_{t+1}^{tr} - y_t^{tr}) - (y_t^{tr} - y_{t-1}^{tr})\right)^2 +$$
$$\lambda sst{=}T{-}jT\Delta yttr{-}uss \qquad (2)$$

where λ_i refers to the adjustment factors that soften the series and $u_{ss}$is the long-run growth rate.

Finally, for the total US and US industrial output series, we only made the correction at the end-of-sample, following the St-Amant and van Norden (1997) procedure. The traditional $\lambda = 1{,}600$ was maintained.

The cyclical component relates the variations of a time series to its secular component, giving it the property of being stationary[13].

To prove statistically that Mexico's economic cycle is determined by the US cycle, it is convenient to prove Granger causality (Table 1).

Table 1

Mexico and US cycles. Grange causality tests, 1980.1-2013.4

Cause / Response	$\mathbf{Y^c_{MXt}}$	$\mathbf{Y^c_{INUSt}}$	$\mathbf{Y^c_{USt}}$
Y^c_{MXt}	----	0.73(12)	1.17(12)
Y^c_{INUSt}	2.21(12)*	----	1.71(12)
Y^c_{USt}	2.75(12)*	4.18(12)*	----

Note: Y^c_{MXt} = Mexico Output's Cycle; Y^c_{INUSt} = US Industrial Output's Cycle; Y^c_{USt} = US Output's Cycle. * Rejects null hypothesis: Non-Granger-causality at 5%; number of lags in parenthesis.

Source: own elaboration based on INEGI and BEA (2014).

The results are conclusive in the sense that for the whole sample there is a statistical precedence of Y_{USt}^c and Y_{INDUSt}^c to Y_{MXt}^c at up to 12 lags for the whole period, and there is no evidence for causality in the opposite direction.

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[12] Sarabia (2010) documents this problem. Many other authors, including Knoteck (2007) and Ball, Leigh and Loungani (2013), also report complications in estimating the trend and, subsequently, the cycle. See Statistical Appendix at the end of the article.

[13] We explicitly demonstrated this feature by applying several unit root tests, which are available upon request.

3.2. Cycle synchronization

To measure the growth cycle synchronization of the two countries, given the fact that Granger causality has been proved and also that all the variables are stationary, it is then justified to do the following OLS regression:

$$Y_{MXt}^{c} = \beta_0 + \beta_1 * Y_{USt}^{c} + \varepsilon_t \qquad (3)$$

Statistical results are reported in Table 2a. The coefficient of determination is relatively high (65%). The synchronization parameter (β_1) is statistically significant and positive, indicating procyclicality. The parameter β_0 has no direct economic meaning but incorporates useful information for regression, even though is not statistically significant.

Table 2a

Y^{c}_{MXt} and Y^{c}_{USt} synchronization. normalized variables, 1980.1-2013.4, OLS estimation

Statistic	
β_0	4.86E-08
t- statistic	(2.75E-11)
β_1	172.0549
t- statistic	(15.60)
R^2	0.6518
Quandt- Andrews Maximum LR F-statistic	3.4093
P value	0.8257
Structural Change	2001.3

Table 2b

Y^{c}_{MXt} and Y^{c}_{USt} synchronization, Bai-Perron multiple-break-point tests

Sequential F-statistic determined breaks:			
Break Test	**F-statistic**	**Scaled F-statistic**	**Critical Value****
0 vs. 1	3.248464	6.496927	11.47
Recursively determined partitions			
Break Test	**Break**	**F-statistic**	**F-statistic**
0 vs. 1	2001.3	3.248464	6.496927

Note: * significant at the 0.05 level. ** Bai-Perron (2003) critical values. Trimming 0.15, Max. breaks 5, Sig. level 0.05.

To prove the structural stability of the estimation, we applied the Quandt-Andrews (1993) and the Bai-Perron (2003) unknown-breakpoint tests, which initially suggest a structural break in 2001.3. Nevertheless, we should reject it at 82% confidence (Table 2a) in the first test, and at 95% in the second test (Table 2b). Therefore, we can fairly conclude that for this estimation there is no structural change.

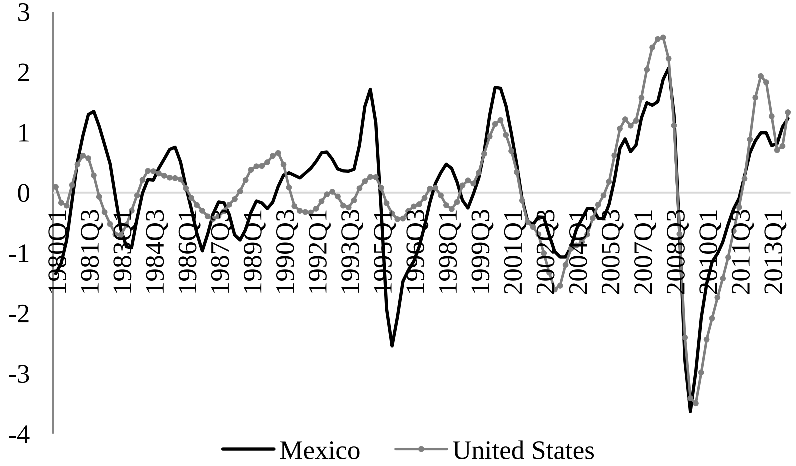
A second evaluation step relies on the fit of the regression (Figure 6). It is noteworthy that just before that date (2001.3), the synchronization was relatively weak and it strengthened considerably afterward. The relatively high volatility of the Mexican cycle up to 2001.3, which tends to disappear in the second phase, should be highlighted. This suggests that the synchronization significantly reduced Mexican GDP volatility relative to that of US GDP.

Since we have already determined that NAFTA linked the Mexican economy to the US industrial structure, in what follows we measured the synchronization process through the following OLS regression:

$$Y^c_{MXt} = \beta_0 + \beta_1 * Y^c_{INUSt} + \varepsilon_t \tag{4}$$

Figure 6

$Y^c_{MXt} - Y^c_{USt}$ Synchronization. normalized variables, 1980.1-2013.4



Note: since we are analyzing variables in different units (MX real pesos and US real dollars), to be comparable, both variables were normalized according to the following normalization procedure: $\frac{x_{it} - \overline{x_t}}{\sigma}$, where σ = standard deviation and $\overline{x_t}$ = arithmetic mean.

Source: own elaboration based on INEGI (2014) and BEA (2014).

Table 3a

Y^c_{MXt}-Y^c_{INUSt} synchronization, Quandt-Andrews OLS estimation, 1980.1-2013.4

Statistic	Period 1980.1 2012.4	1980.1 1994.4	1995.1 2012.4	2001.2 2012.4	2008.3 2013.4
β_0	-0.000000492	4155.27	-4020.24	755.46	6550.92
t- statistic	-2.43E-07	-1.42	-1.82	-0.38	-2.27
β_1	11305.49	-481.22	13112.4	12556.7	14320.8
t- statistic	-12.44	-0.19	-16.74	-21.24	-28.8
R^2	0.5437	0.0006	0.8	0.9093	0.9643
Quandt- Andrews Maximum LR F-statistic	19.1089	11.3567	20.93	9.8931	6.4749
P value	0.0018	0.0544	0.0008	0.0988	0.3523
Structural Change	1995.1	1991.1	2001.1	2008.2	2010.3
Y^c_{INUSt} does not Granger Cause Y^c_{MXt}	2.081 (12)*	0.833 (12)	2.963 (12)*	4.020 (12)*	6.449 (4)*
Y^c_{MXt} does not Granger Cause Y^c_{INUSt}	0.778 (12)	2.069 (12)	0.003 (12)	0.423 (12)	1.190 (4)

Note: * rejects null hypothesis: Non-Granger-Causality at 5%; number of lags in parenthesis.

Source: own elaboration based on INEGI and BEA (2014).

Table 3b

Y^c_{MXt} and Y^c_{INUSt} synchronization, Bai-Perron multiple-break-point tests

Sequential F-statistic determined breaks:

Break Test	F-statistic	Scaled F-statistic	Critical Value**
2 vs. 3 *	11.42544	22.85087	14.03

Recursively determined partitions

Break Test	Break	F-statistic	F-statistic
0 vs. 1 *	1995.1	22.75000	45.50001
1 vs. 2 *	1987.3	9.069477	18.13895
1 vs. 2 *	2001.1	15.41282	30.82565

Note: * significant at the 0.05 level. ** Bai-Perron (2003) critical values. Trimming 0.15, Max. breaks 5, Sig. level 0.05. This test identifies also 2008.2; nevertheless, according to the F values is non-significant.

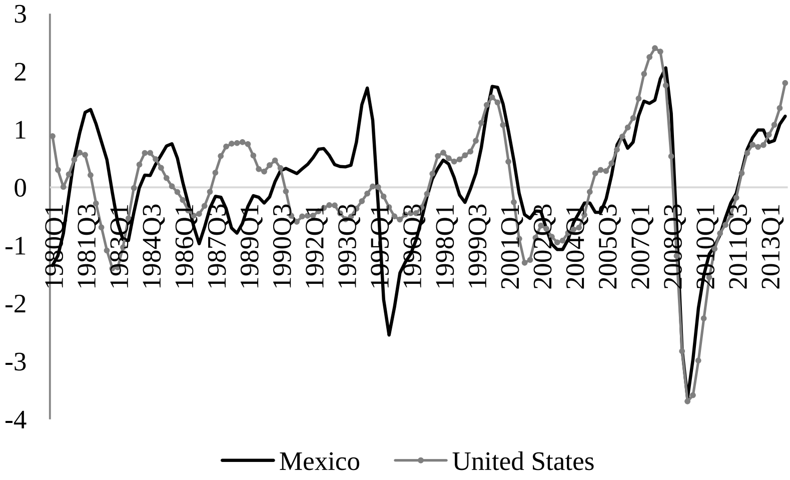
From the results in Table 3 (a and b), the following analysis arises:

1) By applying the Quandt-Andrews (1993) and Bai-Perron (2003) tests, we can suggest that, contrary to the $Y^c_{MXt} - Y^c_{USt}$ stable relation, there is no strong relation between Y^c_{MXt} and Y^c_{INUSt} for the entire estimation period, although we found a relatively high determination coefficient

(54%) and a high synchronization parameter, which is positive and statistically significant. See Table 3a and Figure 7.

Figure 7

$Y^c_{MXt} - Y^c_{INUSt}$ Synchronization. normalized variables, 1980.1-2013.4



Note: since we are analyzing variables in different units (MX real pesos and US real dollars), to be comparable, both variables were normalized according to the following normalization procedure: $\frac{x_{it}-\overline{x_t}}{\sigma}$, where σ = standard deviation and $\overline{x_t}$ = arithmetic mean.
Source: own elaboration based on INEGI and BEA (2014).

2) The same Quant-Andrews (1993) recursive unknown-breakpoint test identified four sub-periods that are critical for analyzing the dynamics of the synchronization process. See Table 3a. Meanwhile, the Bai-Perron (2003) test detected only 3 breaks: 1987.3 1995.1 and 2001.1. See Table 3b.

3) The parameter β_1 –which we have termed “synchronization parameter”– is ordinal in nature; that is, to a higher value of this coefficient corresponds a greater degree of synchronization. It cannot be interpreted as an elasticity or marginal propension. However, the ordinal interpretation is crucial to support our hypothesis.

4) There is a first subsample (1980.1-1994.4), in which many important issues arise: a) the coefficient of determination is zero; b) the synchronization parameter β_1 is negative, very small, and non-significant, and c) there is no Granger Causality. All of this suggests that the cycles had no common features during that period.

5) For the second subsample (1995.1-2012.4) there is a high, positive, and significant synchronization; however, there is an undeniable structural change in 2001.1, which led us to detect two additional sub-periods: 2001.2-2008.2 and 2008.3-2013.4.

6) Taking into account these two sub-periods, we found that all parameters progressively improved as did the regression statistics, to the extent that the R^2 reached 96% and the two structural parameters (β_0 and β_1) increased notably and became significant.

7) Within the last sub-period (2008.3-2013.4), although the Quandt-Andrews (1993) test points to another structural change in 2010.3, it is rejected with a probability of 35% (See Table 3a). Coincidentally, the Bai-Perron test did not register this break (See Table 3b).

8) In sum, we can fairly claim that after 1995.1 there has been an increasing synchronization process, as measured by the coefficient of determination and by β_1 (the synchronization parameter)[14].

9) Figure 8 clearly shows the above-mentioned relationship. Prior to 2001.2, Y_{MXt}^{c} volatility was higher than Y_{INUSt}^{c} and tended to decrease gradually.

4. Economic analysis

Whether the cycle synchronization was advantageous or detrimental for Mexico[15] is beyond the ambitions of this article, since an evaluation of such matters would be entirely subjective. What does fall within the scope of this analysis is the fact that the synchronization was a consequence of the economic integration that Mexico has had with the United States.

This is a very significant concept, particularly because the integration process began in a single direction (i.e. Mexico initially synchronized to the US cycle, and not the other way around). Though this may seem trivial, it becomes quite relevant when we look at the evidence of the growing synchronization: Mexico did find an engine for growth, which it was lacking since the great crisis of 1982, but it also surrendered its sovereignty over

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[14] As recommended by one of the reviewers, we applied Granger Causality Tests for each subsample, which corroborated our main results. See last two rows of Table 4a.

[15] This question was posed by a referee.

economic policy, particularly in the industrial sector, since the country sought to encourage industrial relocation from the United States to Mexico[16].

The economic integration with the United States was initially through trade, finance and investment, with no effects for the labor markets. However, the mobility of the labor force towards the United States accelerated rapidly, generating strong economic links[17]. Furthermore, the fact that the linkage was primarily to US industrial output resulted in Mexico's GDP growth and growth cycle being largely associated with this sector; this can help to explain, along with many other factors, the convergence to very low growth rates (See Table 4).

Table 4

Growth rates, 1980-2013

$\mathbf{Y_{USt}}$	$\mathbf{Y_{INUSt}}$	$\mathbf{Y_{MXt}}$
2.7%	2.1%	2.5%

Note: Y_{USt} = US Output; Y_{INUSt} = US Industrial Output. Index, 2007.2 = 100; Y_{MXt} = Mexico Output.

Source: own elaboration based on INEGI (2014) and BEA (2014).

Conclusion

We estimated the growth cycle synchronization of Mexican GDP to US (total and industrial) output for 1980.1-2013.4. Through the St-Amant and van Norden procedure (1997), we corrected the end-of-sample problem inherent to the HP filter. Following Sarabia (2010), to estimate the secular (trend) component of the Mexican GDP, a λ = 1,096 was assigned. By doing so, we properly estimated the trend and the cycle components of Mexico's GDP.

The main conclusions that can be drawn from the study are the following:

1. The crisis of 1982 resulted in a context marked by: a lost decade; several crises (1982-1983, 1986); stagflation; an external debt crisis; the fall of the economic model; a lack of an engine for growth; and, in general, a crisis of expectations.

2. In this context, Mexico looked to NAFTA for a new engine (model) of growth, a new industrialization, broadening the range of products available in

[16] For a detailed analysis on sectors and regions, in addition to the literature recommended in Section 1, please see also Mejía and Morales (2011).

[17] Although decidedly significant, this topic is beyond the scope of the article and will not be discussed here.

the country, increasing the consumer surplus, opening the economy to boost productivity and competition in the domestic market and reduce prices.

3. Additionally, the country sought to attain macroeconomic stability by linking itself to a strong economy, boost savings and multiply the sources of financing for growth, increase total investment (FDI, FPI and domestic investment) and gain access to new technologies.

4. Once NAFTA was signed, Mexico found that one of the outcomes of synchronization to another economy is sharing its volatility profile. In this case, during the 1990s the United States was already undergoing a process known as the *Great Moderation* (Bernanke, 2004). Although mainly a synchronization to US industrial output was achieved, the process still resulted in a reduction of volatility as a collateral effect.

5. The objective of measuring structural breaks is evaluating the dynamic nature of a process. The analysis presented here demonstrates an important fact: NAFTA prompted a deep alteration in the relationship between the two countries; namely, the two economies went from having a negative synchronization (although statistically non-significant) to having a positive one. This shift resulted from the economic integration, which was itself a product of existing complementarities that encouraged an exploitation of wage disparities and geographic proximity (through FDI, as evidenced by the growth of the manufacturing industry in Mexico), giving rise to the strong connection with the industrial sector of the United States.

6. Twenty years after the introduction of the treaty, economic integration (i.e. financial and trade integration) with the United States has become a key factor for Mexico's growth, causing the domestic economic policy variables to have very little influence over the dynamics of the economic cycle, as evidenced by the result that 96% of the dynamics of Mexico's economic growth cycle is dependent on the US industrial cycle.

7. The most significant shift that resulted from the synchronization process was the sign change after NAFTA came into effect. This is because, along with an increase in trade volumes, an important increase of FDI can be observed, which suggests that the trade integration and the relocation of labor-intensive production (to exploit wage differentials) were among the main transfer mechanisms of this synchronization.

8. We proved (dynamically) Granger causality running from the US total and industrial growth cycles to the Mexican cycle. This information allowed us to identify the business cycles' synchronization and demonstrate that it has been increasing progressively. This highlights the dynamic nature of the cycle

synchronization and represents an original contribution, since the literature on the matter estimates or calculates co movements or partial correlations for whole periods, yielding inherently static calculations that measure partial correlations for specific periods, without taking into consideration structural breaks.

9. By applying the Quandt-Andrews (1993) and the Bai-Perron (2003) unknown- breakpoint tests, we detected endogenously several synchronization periods.

In sum, the synchronization of the Mexican cycle to the US industrial cycle began with the entry into force of NAFTA, which created an integrated industrial production chain.

Statistical Appendix. HP filter criticisms.

First, the a priori selection of the smoothing parameter λ has been criticized, as it is exogenously determined and could potentially affect the calculation of the cycles. This issue was addressed defining a cycle marker by the presence of local maximums and minimums, thus demonstrating the relative unimportance of the smoothing parameter for the identification of cycles.

A second criticism in the literature is directed at the issue of end-of-sample estimation, which was address using the correction developed by St-Amant and van Norden (1997).

A third criticism refers to $\lambda = 1{,}600$, which is the conventional value for quarterly data applied to the US economy in the original paper. Sarabia (2010) proposed $\lambda = 1{,}096$ instead, to more accurately capture the inherently higher volatility of Mexican economic time series. Figure 8 compares the filtering results from the application of both HP filters (1,600 and 1,096)[18].
A key element in the debate over the calculation of the cyclical component is the smoothing parameter. This point is not to be underestimated, since the value of the trend component that the filter calculates will be decisive for the definition of the cycle.

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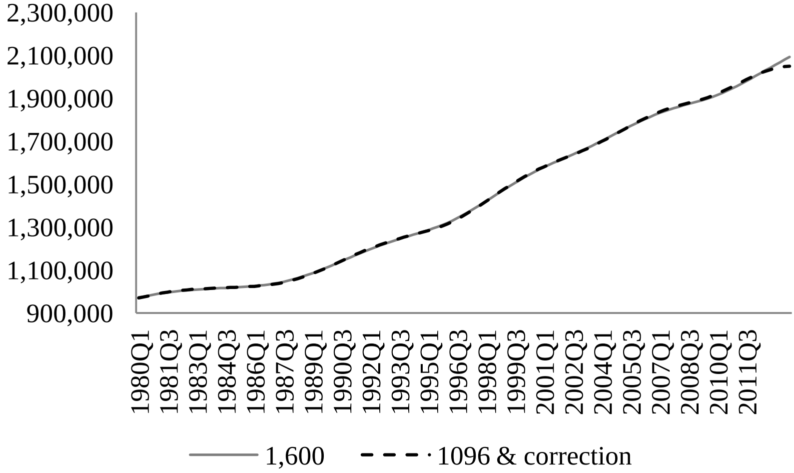
[18] This value is not arbitrary, since a large range of estimates for the Mexican economy in the same period with the smoothing index support its accurate identification (Loría & Salas, 2014).

Figure 8

Mexico's Potential Output with two λ´s and St. Amant and Van Norden correction,1980.1-2013.4, billions of 2005 pesos



Source: own calculations.

To ascertain the effects of the choice of lambda in the determination of the cycle through local maximums and minimums, we calculated 31 different cycles with the same number of different λ´s, based on Guerrero (2011), with smoothing index levels from 92.55% to 94.43%, associated to lambda values from 1000 to 3700.

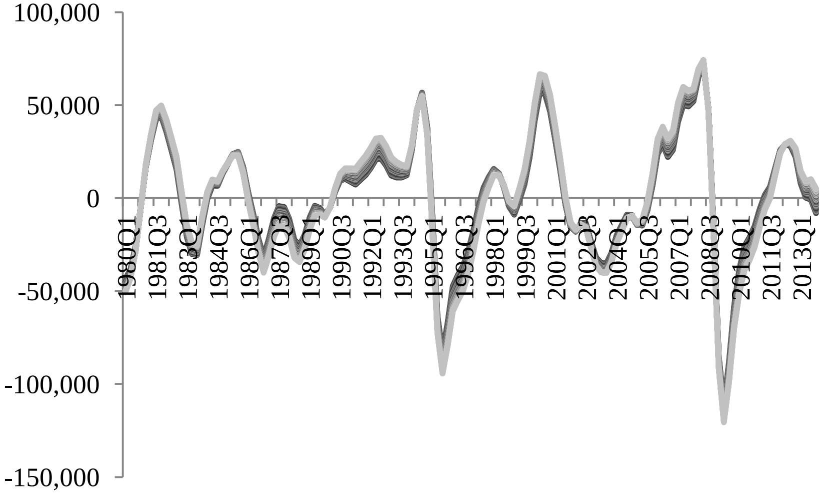
Lower levels, like the 170 lambda used by Guerrero (2011), were omitted, as they result in a relatively low smoothing index of merely 87.01%.

As can be seen in Figure 9, the cycles derived from 31 different λ´s of the Hodrick Prescott filter[19] for the Mexican cycle generally demonstrate a behavior that, although divergent, does present significant regularities in the identification of the growth cycle.

[19] Which began with a lambda of 1,000 and grew at a factor of 90 until 3,700 was reached.

Figure 9

Mexico: Cycles generated by 31 iterations of the HP filter.1980.1- 2012.4



Source: own calculations.

It is thus essential to identify local maximums and minimums, which are values of a function at which the maximum (minimum) is greater (less) than the values around it, but not in relation to all the values of the function. More formally, if $f(x)$ is defined in set *A*, the definitions are:

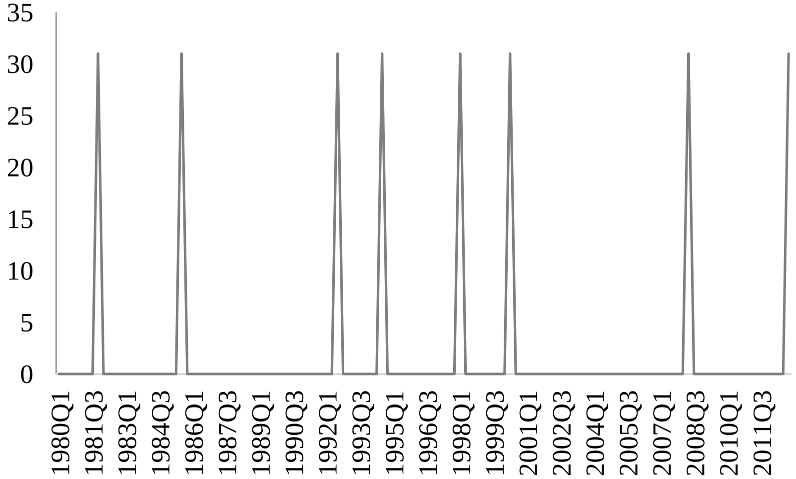
Function f has a local maximum at *c* if there is an interval (α,β) centered around *c* such that $f(x) \leq f(c)$ for every $x \in A(\alpha, \beta)$. Conversely, function f has a local minimum at *d* if there is an interval (α,β) centered around *c* such that $f(d) \leq f(x)$ for every $x \in A(\alpha, \beta)$, (Sydsaeter and Hammond, 1996).

Since the determination of the interval is arbitrary, we choose a value of 3 for α, β, resulting in an interval that encompasses 6 periods, which at a quarterly frequency corresponds to a year and a half.

Figure 10 shows that all 31 different cycle calculations from Figure 9 generate the same maximum values, which can be interpreted as the cycle markers being identical for all calculations, regardless of the lambda value.

Figure 10

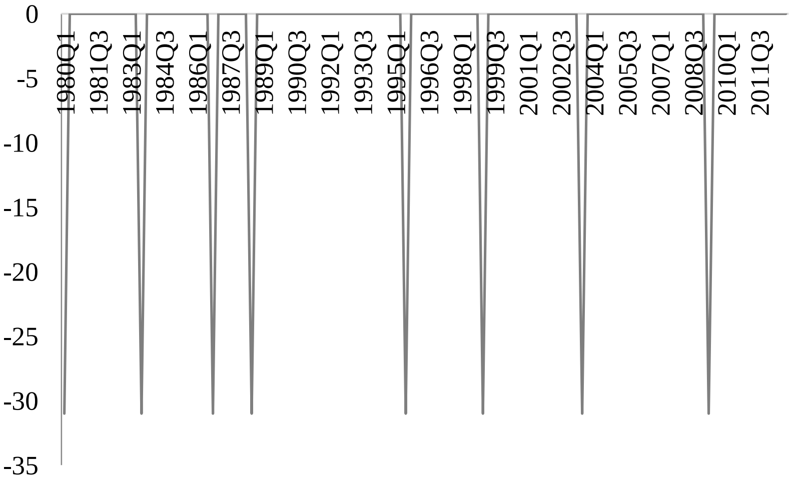
Cycles. Local maximums.1980.1- 2012.4



Source: own calculations.

In the case of minimums (Figure 11) the same relation holds, as all calculations coincide with the same cycle thorough. These results suggest that the lambda value is relatively unimportant within the range proposed in the smoothing index.

Figure 11
Cycles. Local minimums. 1980.1- 2012.4



Source: own calculations.

References

Andrews, D. W. (1993). "Tests for parameter instability and structural change with unknown change point". *Econometrica,* 61(4), 821-856.

Bai, J. and Perron, P. (2003). "Computation and analysis of multiple structural change models". *Journal of Applied Econometrics*, 18(1), 1-22.

Ball, L. M., Leigh, D., and Loungani, P. (2013). Okun's Law: Fit at Fifty? National Bureau of Economic Research, NBER Working Paper No. 18668.

Banxico (2014). *Banco de México*: http://www.banxico.org.mx.

BEA (2014). *U.S Bureau of Economic Analysis*: http://www.bea.gov/index.htm. February 5, 2014.

Bernanke, B. (2004). The Great Moderation: Remarks by Governor Ben S. Bernanke at the meetings of the Eastern Economic Association, Washington, DC February 20, 2004.

Burns, A. F. and Mitchell, W. C. (1946). *Measuring business cycles*. NBER Books.

Castillo, A., Díaz, A. and Fragoso, E. (2004). "Sincronizado entre las economías de México y Estados Unidos: el caso del sector manufacturero". *Comercio Exterior*, 54(7), 620-627.

Chiquiar, D. and Ramos-Francia, M. (2005). "Trade and business-cycle synchronization: Evidence from Mexican and US manufacturing industries". *The North American Journal of Economics and Finance*, *16*(2), 187-216.

Cortez, J. (2008). "Desestacionalización –X12 ARIMA– con efecto calendario Índice de Supermercados". *Instituto Nacional de Estadísticas de Chile, Estudio No. 12*.

Delajara, M. (2012). "Sincronización entre los ciclos económicos de México y Estados Unidos: Nuevos resultados con base en el análisis de los índices coincidentes regionales de México". *Banco de México Working Paper No. 2012-01*.

Delgado, G. (2009). *Estructuras política, económica y social* (2nd ed). México: Pearson Prentice Hall.

Enders, W. (2004). *Applied econometric time series*. John Wiley and Sons.

FRED (2013). Federal Reserve Economic Data http://research.stlouisfed.org/fred2/.

Guerrero, V. (2011). "Medición de la tendencia y el ciclo de una serie de tiempo económica desde una perspectiva estadística". *Realidad, Datos y Espacio: Revista Internacional de Estadística y Geografía*, 2(2), 50-73.

Herrera J. (2004). "Business cycles in Mexico and the United States: Do they share common movements?". *Journal of Applied Economics*, 7(2), 303-323.

Hodrick, R. J. and Prescott, E. C. (1997). "Postwar US business cycles: an empirical investigation". *Journal of Money, Credit, and Banking*, 29(1), 1-16.

INEGI, (2014). *Banco de Información Económica*: http://www.inegi.org.mx/sistemas/bie/.

Knotek, E. S. (2007). "How Useful Is Okun's Law?". *Federal Reserve Bank of Kansas City, Economic Review,* Fourth Quarter, 73-103.

Kose, A., Meredith, G. and Towe, C. (2005). How has NAFTA affected the Mexican economy? Review and evidence. In Langhammer, R. and Vinhas de Souza, L. (Eds.), *Monetary Policy and Macroeconomic Stabilization in Latin America* (35-81). Springer Berlin Heidelberg.

Kydland, F. and Prescott, E. (1990). "Business Cycles: Real Facts and Monetary Myth". *Federal Reserve Bank of Minneapolis Quarterly Review*, 14(2), 3-18.

Loría, E. (2014). TLC: Una evaluación a 20 años. http://www.economia.unam.mx/cempe/PDFs/Reuniones/14-1_una_evaluacion_a_20.pdf

_____and Salas, E. (2014). "Ciclos, crecimiento económico y crisis en México, 1980.1-2013.4". *Estudios Económicos*, 29(2), 131-161.

Lucas Jr, R. (1977). "Understanding business cycles". *Carnegie-Rochester conference series on public policy*, 5(1), 7-29).

Makridakis, S., Wheelwright, S. C. and Hyndman, R. J. (2008). *Forecasting methods and applications*. John Wiley and Sons.

Mejía, P., Gutiérrez, E. and Pérez, J. (2006a). Los claroscuros de la sincronización internacional de los ciclos económicos. *CIENCIA ergo sum*, *13*(2), 133-142.

_____Gutiérrez E. and Farías, C. (2006b). "La sincronización de los ciclos económicos de México y Estados Unidos". *Investigación Económica*, *65*(258), 15-45.

_____Morales, M. (coordinadores) (2011). *Integración y recesión económica en el binomio México-Estados Unidos.* México: Universidad Autónoma del Estado de México.

_____Ochoa, S. and Díaz, M. Á. (2013). "De la recesión a la recuperación: Producción y empleo en México y el Estado de México". *Problemas del Desarrollo*, 44(173).

_____ and Erquizio, A. (2013). *Expansiones y recesiones en los estados de México*. Pearson.

Migration Policy Institute (2014). http://migrationpolicy.org/.

Portnoy, A. (2003). "El proceso hacia la firma del tratado de libre comercio. Una visión histórica de las relaciones entre México y Estados Unidos". *Revista de Humanidades*: *Tecnológico de Monterrey*, (14) 127-162.

Sarabia, A. A. (2010). "El problema al final de la muestra en la estimación de la brecha del producto". *Economía Mexicana NUEVA ÉPOCA*, *19*(1), 5-29.

Serra, J. (2008). La Apertura Comercial de México. LXX Aniversario de La Casa de España. Disponible en: www.sai.com.mx/admin/uploads/archivos/arch201106020315465525Apertura.pdf

Sydsaeter, K. and Hammond, P. (1996). *Matemáticas para el análisis económico*. Pearson, Prentice Hall.

St-Amant, P. and Van Norden, S. (1997). "Measurement of the Output Gap: A discussion of recent research at the Bank of Canada". *Bank of Canada Technical Report No. 79*.

Torres, A. and Vela, O. (2003). Trade integration and synchronization between the business cycles of Mexico and the United States. *The North American Journal of Economics and Finance*, *14*(3), 319-342.

U.S. CENSUS BUREAU (2002). *X-12-ARIMA. Reference Manual, Final Version 0.2*. Washington DC, USA: US Census Bureau.

Vahid, F. and Engle, R. (1993). "Common Trends and Common Cycles". *Journal of Applied Econometrics*, 8(4), 341-360.

World Bank (2013). http://data.worldbank.org/country/mexico.