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Are the Mexican States and the United States Business Cycles Synchronized? Evidence from the Manufacturing Production

Pablo Mejía-Reyes and Jeanett Campos-Chávez*

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Abstract: This paper analyses the degree of synchronization between the Mexican states and the US business cycles by using a growth cycle approach for the period 1997-2007. The business cycle indicators are obtained from seasonally-adjusted monthly manufacturing production. Our results confirm that the Mexican aggregate cycle is highly synchronized with the US business cycle. However, although specific Mexican state cycles are pro-cyclical with respect to the US business cycle, their synchronization is very heterogeneous. In particular, it is strong and robust only for the states of Baja California, Jalisco, Nuevo León and the Federal District, and at least moderate for the state of Mexico and Querétaro. The results are robust with respect to three different detrending methods. Synchronization may be explained by the high volumes of international trade carried out by foreign firms in the case of the central and traditionally industrialized states, and by the "maquila" production in the Northern bordering states. This synchronization may be explained by the vertical integration of the productive processes resulting from the internationalization of production of multinational firms.

Keywords: growth cycles, international synchronization, sub-national business cycles, Mexican states.

¿Se encuentran sincronizados los ciclos económicos de los estados mexicanos con aquellos de Estados Unidos? Evidencia que presenta la producción manufacturera

Resumen: En este documento se analiza la sincronización de los ciclos económicos de los estados mexicanos con el ciclo estadounidense para el periodo 1997-2007, mediante el enfoque de los ciclos de crecimiento. Los indicadores del ciclo se obtuvieron a partir de la producción manufacturera mensual (ajustada por estacionalidad). Nuestros resultados confirman la sincronización del ciclo de la economía nacional con el de los EU. Sin embargo, aunque los ciclos específicos de los estados del país son pro cíclicos, su sincronización es muy heterogénea. En particular, es

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fuerte y consistente solamente para Baja California, el Distrito Federal, Jalisco y Nuevo León, y al menos moderada para el Estado de México y Querétaro. Los resultados son consistentes *(robustos)* respecto a tres métodos de eliminación de la tendencia. La sincronización puede explicarse por los elevados volúmenes de comercio exterior que desarrollan empresas extranjeras en los estados del centro del país y de industrialización tradicional, y por las actividades maquiladoras de los estados fronterizos. Esta sincronización puede explicarse por la integración vertical de los procesos productivos, resultante de la internacionalización de la producción de las empresas transnacionales.

Palabras clave: ciclos de crecimiento, sincronización internacional, ciclos económicos subnacionales, estados mexicanos.

JEL *classification:* E31, E32, F41.

Introduction

The last two decades have witnessed a huge increase in international transactions of goods, services and capitals, as a result of trade and investment liberalization policies instrumented by several countries. Consequently, most economies over the world have become more interrelated, and international transactions have become fundamental mechanisms in the transmission of national shocks to other economies (Anderson, Kwark and Vahid, 1999; Otto, Voss and Willard, 2003; Baxter and Kouparitsas, 2005). In particular, several papers have documented a high synchronization between the business cycles of various groups of countries in a process where the United States (US) has played a central role, given that its business cycles seem to lead those of other economies, especially their most important trade partners (Artis, Krolzig and Toro, 2004; Mejía, 2004; Calderón and Fuentes, 2006; Aiolfi, Catão and Timmerman, 2006; Arora and Vamvakidis, 2001; Torres and Vela, 2003; Osborn, Pérez and Sensier, 2005).

Although several papers addressing the dynamics of international business cycles have been written during the last years for different geographical areas, one topic that has attracted less attention from scholars is related to the sector and regional impacts of national and international fluctuations. This is an important issue, given that specific sector and/or regional cycles can differ from the aggregate one and can absorb the international shocks in a different manner, depending on aspects such as the structure of production, sector and local economic policies, or financial conditions, infrastructure and weather, among others.[1]

[1] See, for example, Norrbin and Schlagenhauf (1988), Altonji and Ham (1990), and Clark (1998) for analyses of the effects of these factors.

In the case of Mexico, several important business cycle stylized facts at an aggregate level have been recently documented,[2] but the analysis of the nature of regional and state business cycles has received less attention in the literature. Although the importance of this subject may be apparent, there are only a few papers addressing this phenomenon. Some of them are those of Ponce (2001), and Del Negro and Ponce (1999), who use a factor model methodology and vector autoregressions, and report that national fluctuations are the main source of state fluctuations. Cuevas, Messmacher and Werner (2003), in turn, argue that the cyclical fluctuations of the Southern region are largely independent, that the central states are more sensible to fiscal and other idiosyncratic perturbations, and that the Northern states' fluctuations are synchronized with the dynamics of the US economy. Recently, Erquizio (2008) has analyzed the dynamics of the cyclical fluctuations of several states and defined a coincident index for each case. Indeed, he concludes that state cycles differ from each other and with respect to the national cycle. Finally, Mejía (2007) uses a classical business cycle approach to document asymmetries in mean, volatility and duration of the Mexican state cycles.

In this context, we aim to contribute to a better understanding of the dynamics of specific business cycles by analysing the degree of synchronization of the Mexican states' business cycles with that of the US. To do so, we apply the conventional methodology introduced by Kydland and Prescott (1990) to measure the degree of co-movement between the corresponding business cycle indicators over the period 1993-2007. Our findings suggest that this synchronization has been heterogeneous across states, and that only a few of them exhibit a high degree of co-movement with the US business cycle; our conjecture is that these results may be explained by the relative importance of international trade, foreign direct investment, "maquila" production and productive structure. The robustness of our results is evaluated by using three alternative de-trending filters, namely the corrected version of Hodrick and Prescott's filter (1997), introduced by Ravn and Uhlig (2002), the Christiano and Fitzgerald's filter (2003), and the annual growth rate.

[2] In particular, Agénor, McDermott and Prasad (2000), Alper (2002) and Mejía (2003a) use the growth cycle approach, advanced by Kydland and Prescott (1990), to determine the variables that follow, lead or are contemporaneous to the business cycle. On the other hand, Mejía (2003b) and Oliveira (2002) follow a classical business cycle view to measure and model business cycle asymmetries. In turn, Chiquiar and Ramos (2004) and Cuevas, Messmacher and Werner (2003) address the analysis of specific business cycles for different economic activities.

This paper is organized as follows. In section I we present some basic statistics about the productive performance of the Mexican states, as well as data on the importance of their international transactions. Section II describes the methodology to be used and the data set. In section III we apply that methodology and discuss the results. Finally, we state some conclusions.

I. Manufacturing production performance and international transactions

The analysis of the business cycle synchronization carried out in this paper is based on manufacturing production indexes, since they are the only indicators of output available on a monthly basis for a reasonable length of time. Some information about the importance of manufacturing production in the Mexican states and the magnitude of its international economic integration is presented in table 1.

Column (1) in table 1 reports the share of manufacturing production (MAN) in gross domestic product (GDP) for each state, which can help us to figure out the relevance of this sector in the state economic dynamics. It can be observed that this sector is especially important in the cases of Coahuila, Querétaro and the state of Mexico, since its participation in total output exceeds 30 per cent, while in another six states that proportion lies above 20 per cent, which equals the corresponding proportion in the national aggregate. In turn, figures of column (2) suggest a high concentration of the national manufacturing production in a few states: above one third of it is generated exclusively in the state of Mexico and the Federal District. If we add the production of the next three most important states, namely Coahuila, Jalisco and Nuevo León, the sum rises above 50 per cent. It is important to highlight that industrialization in these states, except Coahuila, started in the framework of the import substitution strategy instrumented in Mexico from the 1950's. Thus, although there has been some dispersion of production across the Mexican states, especially in favor of the Northern ones, a high concentration still remains (see Messmacher, 2000; Aroca, Bosch and Maloney, 2005; Chiquiar, 2005).[3] One implication of these figures is that the international synchronization of

[3] These authors argue that the exploitation of external economies and concentration in infrastructure and human capital are important factors to explain the heterogeneous distribution of state production in Mexico.

Table 1. Indicators of manufacturing production performance and international integration in the Mexican states (percentages)

State	*Manufacturing performance*				*International integration*		
	MAN_i/GDP_i (1)	MAN_i/MAN (2)	AGR_i (3)	VOL_i (4)	MAQ_i/MAQ (5)	X_i/X (6)	FDI_i/FDI (7)
Aguascalientes (AGS)	29.8	1.8	7.4	9.0	1.4	0.6	0.4
Baja California (BC)	20.5	3.3	4.2	9.4	21.8	11.9	5.1
Coahuila (COA)	37.3	6.1	4.6	6.4	7.5	3.7	1.0
Distrito Federal (DF)	16.7	17.6	1.2	5.8	0.3	28.4	57.3
Durango (DGO)	19.3	1.2	3.2	6.1	1.6	0.7	0.2
Jalisco (JAL)	21.1	6.6	2.0	4.8	4.2	6.2	2.9
Estado de México (MEX)	31.4	16.1	2.1	4.6	1.1	3.1	5.8
Morelos (MOR)	19.8	1.4	3.2	7.9	0.3	0.4	0.7
Nuevo León (NL)	27.3	9.4	4.4	4.6	5.4	7.4	11.1
Puebla (PUE)	27.2	4.7	5.5	10.0	1.7	2.4	2.1
Querétaro (QRO)	33.3	2.8	5.1	6.4	0.5	1.2	0.7
San Luis Potosí (SLP)	25.3	2.2	3.3	5.5	1.1	1.5	0.5
Sinaloa (SIN)	7.3	0.7	2.1	5.6	0.1	0.8	0.2

Table 1. Indicators of manufacturing production performance and international integration in the Mexican states (percentages) (continuation)

State	*Manufacturing performance*				*International integration*		
	MAN_i/GDP_i (1)	MAN_i/MAN (2)	AGR_i (3)	VOL_i (4)	MAQ_i/MAQ (5)	X_i/X (6)	FDI_i/FDI (7)
Sonora (SON)	17.2	2.4	4.4	14.8	6.9	4.1	1.3
Tlaxcala (TLAX)	28.6	0.8	2.7	7.1	0.4	0.3	0.1
Veracruz (VER)	18.0	3.7	1.0	3.9	0.0	0.7	0.3
Yucatán (YUC)	14.0	0.9	4.4	5.0	1.3	0.6	0.2

Sources: Figures in columns (1) through (5) were computed on the basis of data obtained from INEGI's web site: www.inegi.gob.mx; the X_i/X ratio was computed on the basis of Bancomext (2005), and the information of column (7) was obtained from the Secretaría de Economía's web site: www.economia.gob.mx. *Notes:* MAN stands for manufacturing production, GDP for Gross Domestic Product, AGR is the average annual growth rate of manufacturing production, while VOL refers to its standard deviation; MAQ represents the added value of "maquiladora" production; X represents the value of exports, and FDI stands for foreign direct investment. Data in columns (1), (4) and (5) correspond to the period 1997-2006 and were computed on the basis of annual real quantities. In turn, figures in columns (2), (3) and (7) refer to the period 1997-2007; those of the former two columns were computed on the basis of monthly indexes of volume, while the latter is based on quarterly figures. Finally, column (6) contains data for 2004. Variables with the subscript *i* refer to the *i*-th state, whereas those without that subscript indicate the corresponding national aggregate.

different Mexican aggregate output measures reported by some authors may be explained by the dynamics of these few states.

The average annual growth rates and volatility of manufacturing production are presented in columns (3) and (4). It is noticeable that manufacturing production exhibits a lower growth in those states where it represents a higher proportion of the national aggregate: in the average, the state of Mexico, Jalisco and the Federal District have presented the lowest rates over the period 1997-2007 (2.1, 2.0 and 1.2, respectively). However, as an advantage, these growth rates are some of the most stable in the sample, as measured by their standard deviations. On the contrary, some of the states with higher growth rates are also the most volatile, such as Aguascalientes, Baja California, Puebla and Sonora.

On the other hand, from the international integration perspective, several papers have highlighted the importance of "maquila" production both as a part of the national manufacturing output as well as a significant link to the US productive activities through intra-industry and intra-firm trade[4] (Hanson, 1998; Acevedo, 2002; Mejía, 2003c; Bergin, Feenstra and Hanson, 2008; Waldkirch, 2008). To illustrate this issue, column (5) in table 1 shows the share of each state "maquila" production in the total of the economy. The concentration degree is higher in the case of this variable: Baja California produces more than 20 per cent of the national "maquila" production. Although far away from that figure, "maquiladoras" have also some importance in other frontier states, such as Coahuila (7.5%), Sonora (6.9%) and Nuevo León (5.4%). The rest of the national "maquila" production is distributed among the other states (especially Jalisco, with 4.2%). Thus, "maquiladoras" are expected to play an important role in the transmission of external shocks in these states.

In turn, international synchronization of national and regional business cycles can result from the transmission of specific shocks from one economy to another through international transactions. In particular, some authors have argued that international trade is a central mechanism in such process, especially when it assumes the form of intra-industry trade, with a high component of intra-firma transactions; moreover, trade liberalization may enhance its effects (see Canova and Dellas, 1993; Anderson, Kwark and Vahid, 1999; Otto, Voss and Willard, 2003; Baxter and Kouparitsas, 2005; Osborn, Pérez and Sensier, 2005). On the other hand, foreign direct investment (FDI) has contributed to the internationalization of production, which has caused it to become an important transmission channel of shocks hitting the source and the host economies, especially in this era of globalization (Hanson and Slaughter, 2003; Jansen and Stokman, 2003). Furthermore, some papers have highlighted the importance of multinational firms in the recently observed increase in international trade flows resulting from vertical integration of their productive processes.[5] To shed some light on the importance of these variables in the

[4] "Maquila" production refers to the (duty-free) importation of components to be assembled and re-exported by small local firms. In Mexico, these activities are strongly linked to US firms' operations, especially in the Northern border, and based on the employment of cheap labor. The importance of "maquiladoras" is evident from the fact that their exports represent nearly 50 per cent of total exports.

[5] Essentially, there are two approaches to analyze the relationship between FDI and international trade. First, the source country may invest in the destination country to substitute trade. This is usually motivated by the desire to be close to customer markets due to high trade

integration of the Mexican states, columns (6) and (7) report the structure of exports (X_i/X) and foreign direct investment (FDI_i/FDI) by state, respectively.[6] A very high concentration is observed in these two cases: according to the data, the Federal District stands for about 28 per cent of total exports, and hosts above 57 per cent of foreign direct investment. Although this information should be taken with caution given that it is strongly affected by the addressed issue, it suggests that Baja California, Jalisco, Nuevo León and Sonora stand out as exporters, while Nuevo León, the state of Mexico and Baja California have become the most important destinations for FDI in Mexico. In line with the facts reported at the national level (Kim, 1997; Máttar, Moreno and Peres, 2003; and Waldkirch, 2008), the concentration of these international transactions in a few states suggests the existence of vertical integration in their productive processes, as well as an important role of FDI in international trade in the Mexican states.

In summary, these basic figures about the importance of manufacturing activities and the magnitude of their international transactions suggest that only a few states have the conditions to be synchronized in some magnitude with the international (US) business cycle. The rest of the paper is devoted to address more formally this issue.

II. Methodological issues and data set

In this paper we use the growth cycle methodology introduced by Kydland and Prescott (1990). Following the spirit of Lucas (1977), these authors define the cycle (indicator) as the deviations of output (in logarithms) from a stochastic trend, which can be estimated by different alternative filters. The stylized facts of the business cycle correspond to the co-movements between the cycle indicator and the cyclical component of other variables. In turn,

costs; then, firms run similar operations at different locations. Second, instead, FDI may increase trade transactions between the source and the host countries when multinational firms split up the production process, developing the parts over different countries on the basis of their comparative advantages (see Fontagné, 1999, and references therein).

[6] Among the difficulties to perform economic analysis of the Mexican state economies is the lack of reliable statistical data. One major issue that explains this is the *fiscal address problem*: many firms report their production, commercialization and investment activities in their headquarters' address, despite the fact that they are generated in the physical plants located somewhere else. Consequently, economic indicators can be overestimated for the Federal District and underestimated for the rest of the states. This problem is especially relevant in the estimation of international trade and FDI statistics. Because of this, our analysis about the role of these variables in the international synchronization can only be *indicative*.

business cycle synchronization refers to the movement in phase of the business cycle indicators of different countries, states or productive sectors.[7]

In terms of the subject addressed in this paper, the co-movement between the business cycle of the US (y_t) and the specific cycle of the *j*th Mexican state (x_{jm}) is computed by means of the correlation coefficient *p(m)*, for *m* equal to 0, ±1, ±2,..., ±12.[8] On the basis of these calculations we determine the direction and the time profile of the co-movements. In particular, when the contemporaneous values of the specific cycle of state *j* change in the same (opposite) direction of those of the US business cycle, the cycle of that state is said to be *pro-cyclical* (*contra-cyclical*) and $p(m) > 0$ ($p(m) < 0$). In turn, if the highest correlation coefficient (in absolute value) between y_t and x_{jm} corresponds to $m < 0$ ($m > 0$), then the *j*th state is defined to be *leading* (*lagging*) the US cycle. Finally, if the maximum value of $|p(m)|$ corresponds to $m = 0$, we claim that both cycles are *contemporaneous*. Notice that given the relative sizes of the Mexican states and the US economy, only the lagging and the contemporaneous cases can be considered as relevant in terms of the transmission of fluctuations to Mexico. In addition, we classify the intensity of the co-movement as strong if the correlation coefficient is greater than 0.7, as moderate if it lies between 0.5 and 0.7, and as weak if it is lower than 0.5.

On the other hand, after Canova (1998) argued that the business cycle properties depend on the detrending filter, different filters are commonly applied to obtain alternative business cycle indicators to check the robustness of the results: if they are qualitatively similar, it is said that those results are robust to the filter. Therefore, in this paper we apply three different detrending filters. First, we apply one of the most popular filters in the literature, the one introduced by Hodrick and Prescott (1997). Briefly, Hodrick and Prescott's approach is based on the idea that a series y_t can be decomposed into a stochastic and smooth trend τ_t and a stationary component $c_t = y_t - \tau_t$; the latter becomes the business cycle indicator.[9] Although

[7] In that sense, this approach is more interested in the analysis of the coincidence of movements above and below the trend of two different series, rather than in the characterization of the business cycle regimes. An approach addressing these aspects is the classical business cycle view (see Mejía, 2003b, 2007).

[8] Specifically, *p(m)* is computed to measure the association between y_t and several lags and leads of x_{jm}. Notice that the correlation coefficients simply measure the statistical association between two stationary variables; they do not capture causality in any sense.

[9] This filter is a two-sided linear filter that computes the smoothed series τ_t of y_t by minimizing the variance of y around τ. The computation of τ involves the penalty parameter λ which controls the smoothness of the trend series τ: larger values of λ generate a smoother trend. In

this filter has been subject to several criticisms (see, for example, Harvey and Jaeger, 1993, and Cogley and Nason, 1995), in this paper we adopt the view of Ravn and Uhlig (2002), who argue that it has resisted those criticisms as well as the pass of time. Thus, rather than introducing another filter, they modify it to be insensible to changes in the periodicity of the data.[10] We use this version of the filter to obtain the business cycle indicators and call it the corrected Hodrick-Prescott filter (HPC filter, hereafter).

Despite its popularity, the HPC filter presents two important limitations of interest for the purposes of this paper: it yields a highly volatile cycle indicator[11] and becomes ill-defined at the beginning and the end of the sample. To overcome these shortcomings, we also apply the band-pass filter proposed by Christiano and Fitzgerald (2003), hereafter CF filter. Regarding the first limitation, the problem derives from the fact that the HPC filter decomposes a series y_t into a smooth trend τ_t and a stationary component c_t, which leaves the high-frequency components of the series as part of the latter. On the contrary, a band-pass CF filter decomposes a time series into three components, a stochastic trend τ_t, a cyclical component c_t and an irregular component ε_t, and associates each to different frequencies. In particular, the filter "passes" through the cycles in a band (specifying a range for its duration) and "filters" out the remaining components.[12] This decomposition allows us to obtain a smoother cyclical indicator for the Mexican states, which can be more comparable to the corresponding US indicator. On the other hand, the band-pass filters are computed as a two-sided weighted moving average of the data, which provokes problems at the extremes of the sample, since a fixed number of leads and lags is used, such as in the Baxter and King's (1999) filter. The CF filter version used in this paper is the most general one, and the weights on the leads and lags are allowed to differ, so the filtered series can be computed to the ends of the original sample.

the extremes, when $\lambda = 0, y_t = \tau_t$ and $\lambda \to \infty$, τ_t approximates a linear trend. Hodrick and Prescott suggest the use of a value of $\lambda = 14\,400$ for monthly data.

[10] Ravn and Uhlig (2002) show that the trend and cycle components of series with different time frequency resemble more to each other when the smoothing parameter $\lambda = 129\,600$, instead of the conventional value of 14 400 for monthly data.

[11] This fact becomes a major problem when we compare the business cycles of an emerging economy and a developed economy, since the cycles of the former usually are more volatile than those of the latter.

[12] Following the definitions of Burns and Mitchell (1946), durations of 1.5 to 8 years are conventionally considered in the application of the CF filter. Thus, the trend and the irregular component would lie outside this range.

Finally, the annual growth rate (AGR) is also applied, since it has the advantage of being less erratic than the monthly growth rates. In addition, in an opposite way to the previous two filters, the AGR is related to the so-called classical business cycle approach, which examines the underlying directions of change of the economy in terms of increases (expansions) or decreases (recessions) in the level of output (see Osborn, Pérez and Sensier, 2005). In that sense, this filter allows for a complementary analysis.

Regarding the data set, we consider the experience of the seventeen Mexican states listed in table 1; our choice of states was based on the availability of data. The analysis is performed using the monthly seasonally-adjusted manufacturing production index, collected *in situ* for each state and reported by the Instituto Nacional de Estadística y Geografía (INEGI) over the largest possible sample period, 1993:01-2007:12. For the US economy the business cycle indicator is also obtained from the seasonally-adjusted manufacturing production index, for the sake of consistency.

Two aspects related to the data set must be clarified. First, in our view, the manufacturing production index is a good indicator of the states' business cycles. In general, some authors have suggested the use of industrial production instead of GDP in the business cycle analysis, since the former roughly corresponds to output in the traded goods sector (excluding primary commodities) and is most closely related to what traditionally are thought of as business cycle shocks, either exogenous or policy determined.[13] In our case, industrial production measures are not available for Mexico's states; yet, the same arguments can be extended to the manufacturing production, since around 85 per cent of total exports correspond to manufactured goods, a feature that makes this sector very sensitive to external fluctuations. Additionally, some papers have documented a strong association between industrial and manufacturing production for Mexico (Mejía, 2003a), while others have used manufacturing measures as business cycle indicators to analyze international synchronization (Castillo, Díaz and Fragoso, 2004; Chiquiar and Ramos, 2004). Second, although the sample period may seem to be short, it is important to take into account that the full sample (1993-2007) includes two full cycles of the Mexican

[13] Furthermore, the use of GDP data for measuring business cycle activity in a developing country can be problematic. Agriculture, which still accounts for a large share of aggregate output in several states (including some in our sample), is influenced more by weather conditions than by cyclical factors. Additionally, poor measurement of services and informal sector activities may also introduce significant biases (see Agénor, McDermott and Prasad, 2000).

economy, while the shorter sample considered below (1997-2007) corresponds to 1.5 cycles, two expansions and one recession. Moreover, several papers have argued that the synchronization of the Mexican economy to the US business cycle is really evident from the second half of the nineties (see Castillo, Díaz and Fragoso, 2004, and Mejía, Gutiérrez and Farías, 2006a). Thus, in our view, the data set is a sensible one to address the issue we are interested in.

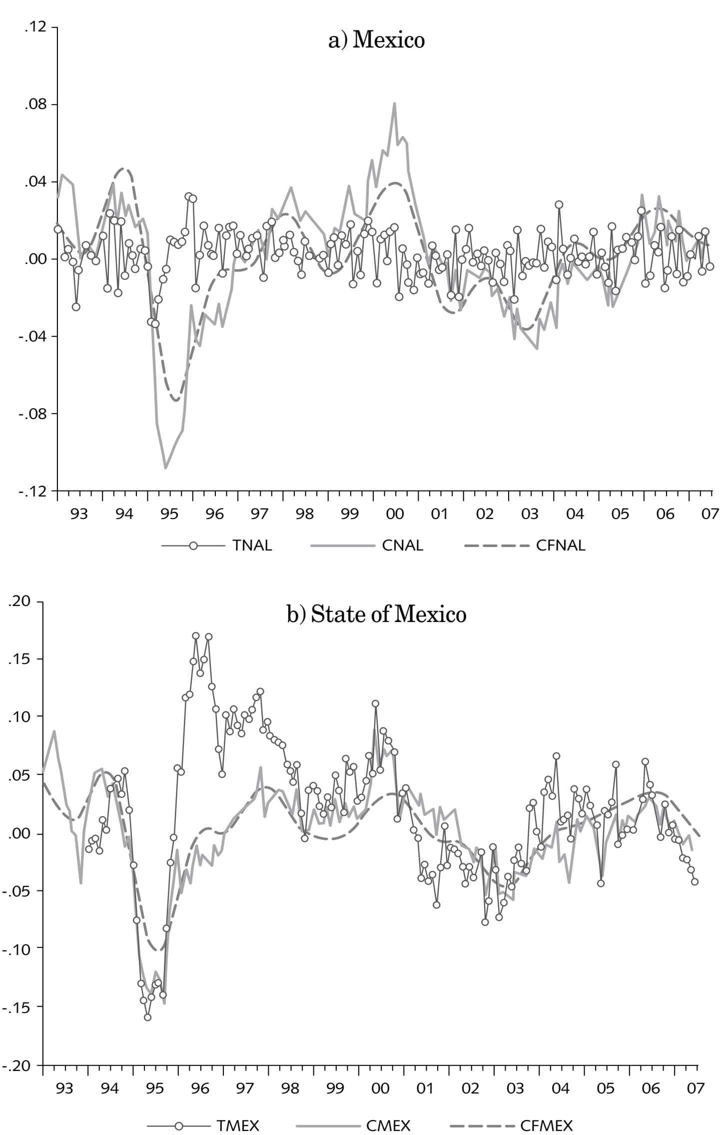
III. Mexican states and US business cycles synchronization

The above outlined methodology is applied to measure the degree of synchronization between the Mexican states and the US business cycles. The cyclical components obtained by the application of the three detrending methods are illustrated for the cases of Mexico and the state of Mexico in figure 1. The business cycle indicators are computed in the same manner for each Mexican state as well as for the corresponding aggregate series of Mexico and the US. Figure 2 represents the evolution over time of the business cycle indicators of the US, Mexico and the state of Mexico. Panel (a) shows the dynamics of the cyclical indicators of Mexico and the US for the HPC filter, while panel (b) describes the same dynamics for the state of Mexico and the US. In both cases a close correlation is evident, especially after the 1995 recession. Notice also that the higher volatility of the Mexican measures (obtained with the HPC filter) does not significantly affect this apparent correlation, as it can be observed in the scatter diagrams depicted in figure 3.

The 1995 recession experienced by Mexico was very deep, and was not accompanied by a similar episode in the US: this economy only lied below its trend during that period, but it did not experience any recession. The lack of synchronization between the business cycles of both countries around 1995 causes a significant reduction in the correlation coefficients. Therefore, to isolate its effects and concentrate in the US business cycle effects, the Kydland and Prescott's (1990) methodology is developed for two subperiods, 1993-2007 and 1997-2007.[14] In our view, this is a sensible exercise and is in line with what some other authors have reported in the literature. For example, at an aggregate level, Castillo, Díaz and Fragoso

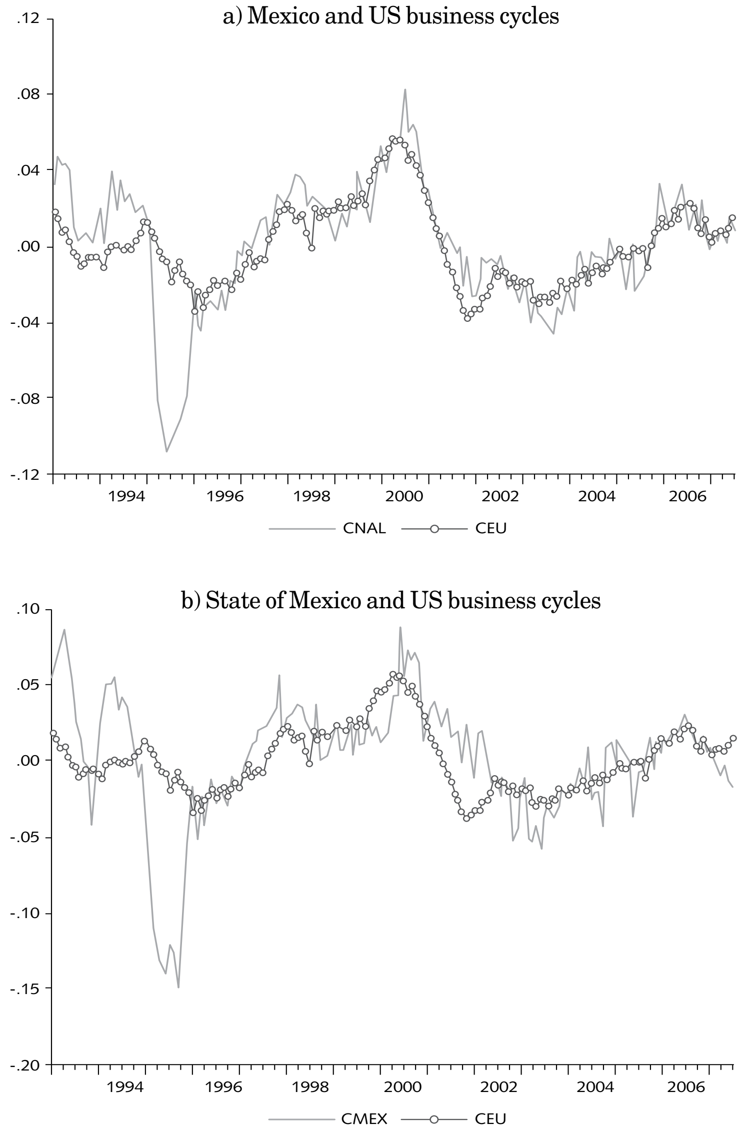
[14] Notice that the detrending filters are applied to the whole sample, while the co-movement analysis is carried out for shorter periods of time because of the argued reasons. This has the advantage that the extreme sample problems of the HPC filter are only present at the beginning of the first period and at the end of the latter.

Figure 1. Business cycle indicators of Mexico and the state of Mexico



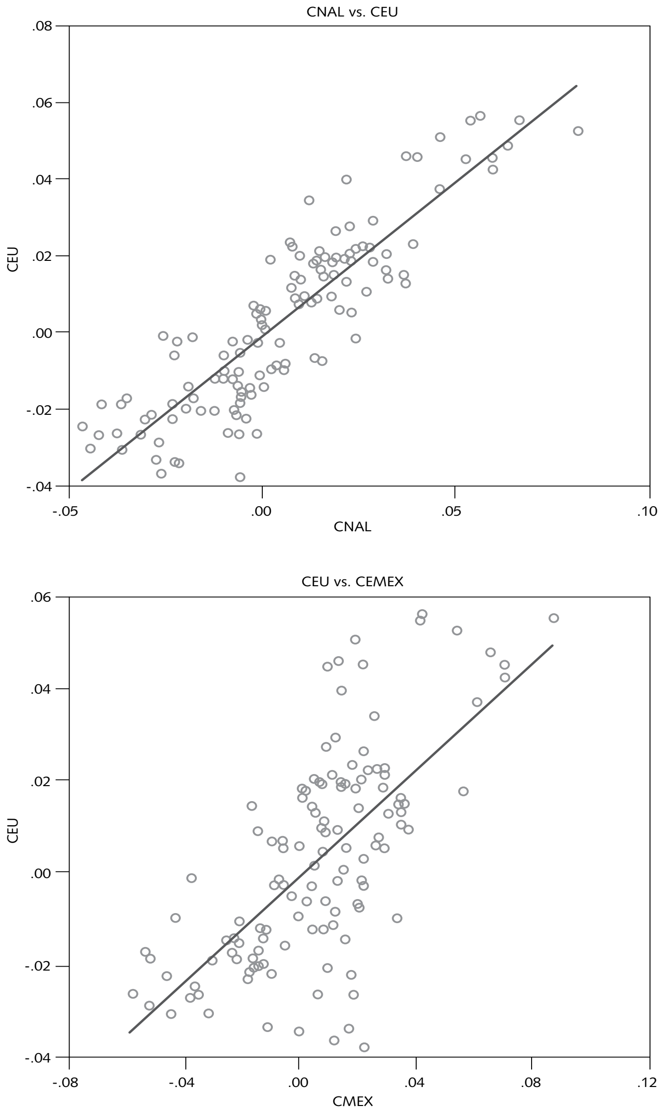
Source: Authors' own elaboration on the basis of data obtained from INEGI (www.inegi.gob.mx). See also the main text for further details. *Note:* TNAL and TMEX stand for the annual growth rate of the manufacturing production of the country and the state of Mexico, respectively. In turn, CNAL and CMEX on the one hand, and CFNAL and CFMEX on the other, refer to the cyclical component of their manufacturing production, obtained with the HPC filter and the CF filter respectively.

Figure 2. Co-movement of business cycles (HPC detrended series)



Source: Authors' own elaboration on the basis of data obtained from INEGI (www.inegi.gob.mx) for Mexico and the state of Mexico, and from the Bureau of Economic Analysis (www.bea.gov) for the United States. See also the main text for further details. *Note:* CNAL, CEU and CMEX stand for the HPC detrended series of Mexico, the US and the state of Mexico, respectively.

Figure 3. Association of business cycles (HPC detrended series) 1997-2007



Source: Authors' own elaboration on the basis of data obtained from INEGI (www.inegi.gob.mx) for Mexico and the state of Mexico, and from the Bureau of Economic Analysis (www.bea.gov) for the United States. See also the main text for further details. *Note:* CNAL, CEU and CMEX stand for the HPC detrended series of Mexico, the US and the state of Mexico, respectively.

(2004), Mejía, Gutiérrez and Farías (2006a), and Mejía, Gutiérrez and Pérez (2006b) argue that the synchronization between different manufacturing variables and the US cycle has become clear only since the late nineties. Indeed, our results show that when the period around the 1995 recession is excluded, the synchronization degree increases substantially. Thus, in the main text of this paper we describe in detail our findings for the 1997-2007 period, but the results for the full sample are reported in appendix 1 for information purposes.

Table 2 contains the results of the co-movement analysis for the three filters. The first two columns contain the correlations between the contemporaneous values of the business cycle indicator of state *j* and that of the US. These computations allow us to define the magnitude of the synchronization and its cyclicality. The last three columns contain information about the time profile: they present the number of periods by which the Mexican state *j* leads or lags the US cycle, which is stated on the basis of the greatest correlation coefficient (in absolute value). Of course, given the relative size of the involved economies, it makes more sense to pay attention to the cases when the cycle of state *j* lags the US business cycle. The discussion of our findings is in order.

As it has been documented previously, we find a strong robust synchronization between the Mexican aggregate business cycle and the US business cycle: the correlation coefficient between the contemporaneous values of these two cycle indicators is equal to 0.83, at least. In turn, a strong synchronization with the US cycles is also found for Baja California, the Federal District, Jalisco and Nuevo León. In two other cases synchronization is moderate, at least with correlation coefficients equal to 0.60 for the CF filter, and greater than 0.68 for the other two filters in the case of the state of Mexico. In turn, for Querétaro the maximum correlation coefficients are 0.67 and 0.69 for the HPC and the CF filters respectively, while for the AGR the contemporaneous correlation coefficient equals 0.76 and its maximum value amounts to 0.78.[15]

On the other hand, there is a moderately robust synchronization with the US business cycle in the cases of Aguascalientes, Coahuila, Puebla and San Luis Potosí. Another four states, Sonora, Yucatán, Sinaloa and

[15] According to the maximum (in absolute value) correlation coefficients, some states' business cycles lead the US one, which does not seem to be a sensible conclusion. However, in most of these cases the contemporaneous correlation coefficients reveal the same degree of synchronization, and when that is not the case, the differences are very small. Therefore, our conclusions do not change in any sense.

Table 2. Cross correlation between the Mexican states business cycles and the US business cycle, 1997-2007

State	*Contemporaneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads / lags*
			Corrected Hodrick-Prescott Filter		
BC	**0.81**	**Pro**	**0.83**	**leads**	**2**
NL	**0.80**	**Pro**	**0.80**	**contemp**	**0**
JAL	**0.75**	**Pro**	**0.75**	**contemp**	**0**
MEX	**0.68**	**Pro**	**0.72**	**leads**	**4**
DF	**0.71**	**Pro**	**0.71**	**contemp**	**0**
QRO	*0.65*	*Pro*	*0.67*	*lags*	*1*
SLP	*0.59*	*Pro*	*0.60*	*lags*	*3*
SON	*0.59*	*Pro*	*0.60*	*leads*	*1*
DGO	*0.36*	*Pro*	*0.60*	*lags*	*9*
PUE	*0.54*	*Pro*	*0.56*	*lags*	*4*
YUC	*0.41*	*Pro*	*0.56*	*leads*	*9*
AGS	*0.41*	*Pro*	*0.52*	*leads*	*4*
COAH	*0.25*	*Pro*	*0.52*	*lags*	*9*
MOR	0.33	Pro	0.45	leads	7
TLAX	0.40	Pro	0.40	contemp	0
SIN	0.16	Pro	0.27	leads	7
VER	0.07	Pro	0.15	leads	7
National	**0.89**	**Pro**	**0.89**	**contemp**	**0**
			Christiano-Fitzgerald Filter		
BC	**0.89**	**Pro**	**0.91**	**leads**	**3**
NL	**0.68**	**Pro**	**0.78**	**lags**	**1**
JAL	**0.69**	**Pro**	**0.77**	**lags**	**2**

Table 2. Cross correlation between the Mexican states business cycles and the US business cycle, 1997-2007 (continuation)

State	*Contemporaneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads / lags*
MEX	*0.60*	*Pro*	*0.60*	*contemp*	*0*
DF	**0.65**	**Pro**	**0.73**	**lags**	**1**
QRO	*0.53*	*Pro*	*0.69*	*lags*	*2*
SLP	*0.60*	*Pro*	*0.62*	*lags*	*1*
SON	*0.59*	*Pro*	*0.63*	*leads*	*5*
DGO	0.11	Pro	0.47	lags	9
PUE	*0.46*	*Pro*	*0.56*	*lags*	*3*
YUC	*0.47*	*Pro*	*0.60*	*leads*	*9*
AGS	*0.63*	*Pro*	*0.66*	*leads*	*4*
COAH	*0.17*	*Pro*	*-0.69*	*leads*	*9*
MOR	0.22	Pro	0.25	leads	5
TLAX	0.29	Pro	0.29	contemp	0
SIN	*0.55*	*Pro*	*0.60*	*leads*	*6*
VER	0.03	Pro	-0.32	lags	9
National	**0.83**	**Pro**	**0.87**	**contemp**	**0**
			Annual growth rates		
BC	**0.79**	**Pro**	**0.83**	**leads**	**3**
NL	**0.82**	**Pro**	**0.83**	**lags**	**1**
JAL	**0.76**	**Pro**	**0.76**	**contemp**	**0**
MEX	**0.70**	**Pro**	**0.73**	**leads**	**4**
DF	**0.77**	**Pro**	**0.78**	**lags**	**1**
QRO	**0.76**	**Pro**	**0.78**	**lags**	**1**

Table 2. Cross correlation between the Mexican states business cycles and the US business cycle, 1997-2007 (continuation)

State	*Contemporaneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads /lags*
SLP	*0.57*	*Pro*	*0.59*	*lags*	*3*
SON	*0.59*	*Pro*	*0.63*	*leads*	*5*
DGO	0.41	Pro	0.48	lags	9
PUE	*0.52*	*Pro*	*0.53*	*lags*	*1*
YUC	0.44	Pro	0.47	leads	9
AGS	*0.48*	*Pro*	*0.53*	*leads*	*3*
COAH	*0.38*	*Pro*	*0.51*	*lags*	*6*
MOR	0.39	Pro	0.49	leads	7
TLAX	0.43	Pro	0.43	contemp	0
SIN	0.01	Pro	0.20	leads	9
VER	0.09	Pro	0.17	leads	7
National	**0.90**	**Pro**	**0.90**	**contemp**	**0**

Source: Authors' own computations. *Note:* A strong (moderate) synchronization is indicated in bold (cursives). The states have been ordered according to the maximum correlation coefficient computed for the HPC detrended series.

Durango have experienced a synchronization which is moderate at most; this, of course, can not be considered a robust result. Finally, in all the other cases there is a weak synchronization with the US business cycle.

Our findings are summarized in maps 1 and 2, where different colors and marks have been used to distinguish the results for each filter. HPC, CF and AGR stand for the results obtained with the corrected Hodrick-Prescott filter, the Christiano and Fitzgerald filter and the annual growth rate respectively. Map 1 shows the states having a strong synchronization with the US cycle, while map 2 does the same for a moderate synchronization. These images evidence a high concentration of the synchronization process in a few central and Northern states, as well as the robustness of our results through those filters.

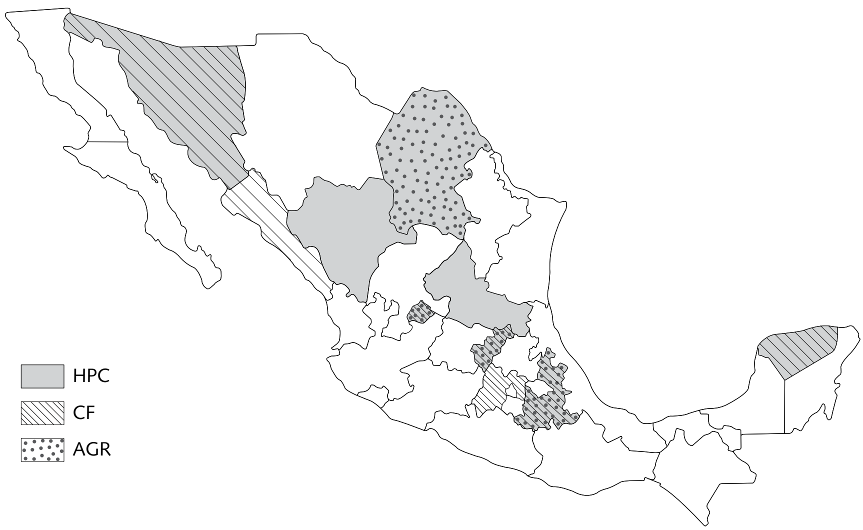
Map 1. Strong synchronization between the Mexican states and the US business cycles

Source: Authors' own elaboration on the basis of the correlation coefficients presented in Table 2. *Note:* A strong synchronization is defined by a correlation coefficient greater than 0.7. Regarding the notation, HPC, CF and AGR stand for the results obtained with the series detrended with the corresponding filters.

At this point it is important to question "what explains synchronization with the US business cycle at state level in Mexico?" Different factors play a central role in the answer. First, the share in total manufacturing production of states at least moderately correlated with the US business cycle may explain the high synchronization reported for the economy as a whole. In particular, the manufacturing production of the four robust and strongly correlated states (BC, DF, JAL and NL) represented around 50 per cent of the national manufacturing production between 1997 and 2006, while the corresponding figure for the six at least moderately correlated states (MEX and QRO in addition to the previous four) was 76.6 per cent for the same period.[16] Thus, it is sensible to think that the cyclical synchronization of

[16] Information to compute the structure of production is available up to 2006.

Map 2. Moderate synchronization between the Mexican states and the US business cycles



Source: Authors' own elaboration on the basis of the correlation coefficients presented in Table 2. *Note:* A moderate synchronization is defined by a correlation coefficient greater than 0.5 and lower or equal to 0.7. Regarding the notation, HPC, CF and AGR stand for the results obtained with the series detrended with the corresponding filters.

these states explains a high proportion of the aggregate synchronization reported here and in some other papers.

Second, the importance of Jalisco, Nuevo León, the state of Mexico and the Federal District in the synchronization with the US business cycle suggests that there has been a reorientation of their manufacturing production processes. These states started industrialization in the context of the import substitution strategy, implemented from the 1940's onwards. A key incentive to attract investment, both domestic and foreign, was the availability of a protected domestic market. Consequently, many important productive activities were developed, and many multinational firms settled in the country at that time. For several decades, the economy as a whole had a good performance. Afterwards, the structural change in the development strategy (instrumented from the early 1980's) to an open and market economy, shifted the attention of producers and policy makers from the internal to the external market; this seems to be the case of the aforementioned states.

Third, as we have advanced above, international transactions seem to play a central role, especially in the context of globalization.[17] For the particular case of Mexico, international trade and foreign direct investment may have become important transmission mechanisms of external shocks, given that multinational firms adapted better than the national ones to the open and market economy built up from the mid-80's: their experience in the international markets was an important advantage to commercialize their products; it became a fundamental factor for their successful exportation performance (Kim, 1997; and Máttar, Moreno, and Peres, 2003).[18] Furthermore, multinational firms have split up their production processes; this has generated a vertical integration of the Mexican local activities to the international production flows. These phenomena have not only increased the correlation between FDI and trade (Waldkirch, 2008), but may have contributed to the synchronization of local business cycles with the international cycles.

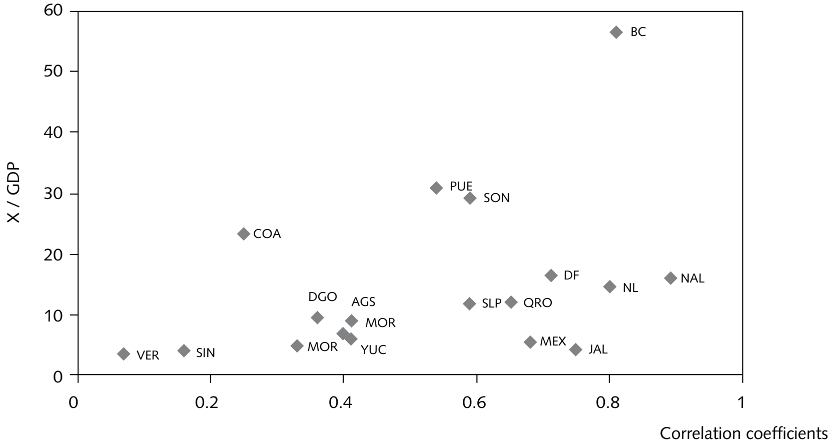
These dynamics may explain the high levels of synchronization of traditionally industrialized states (such as Jalisco, Nuevo León, the Federal District and the state of Mexico) with the US cycles, given that they concentrate a high proportion of FDI (see table 1). Therefore, it is sensible to argue that multinational firms have played a central role in the reorientation of the productive processes of these states, from supplying the domestic market to exportation activities.

To shed some light on the importance of these factors in the explanation of our findings, figure 4 presents the relationship between the estimated correlation coefficients and the ratio of exports to gross domestic product (X/GDP) for each state, while figure 5 depicts the relationship between the estimated correlation coefficients and the ratio of foreign direct investment to gross domestic product (FDI/GDP) for each state too. A posi-

[17] According to recent studies, international business cycle synchronization can be explained by exchange rate stability, the integration of financial markets, a common propensity to adopt new technologies, bilateral international trade, common shocks, foreign direct investment, vertical production integration and similar production structures, among others (see, for example, Otto, Voss and Willard, 2003; Baxter and Kouparitsas, 2005; Kose and Yi, 2001; and Anderson, Kwark and Vahid, 1999).

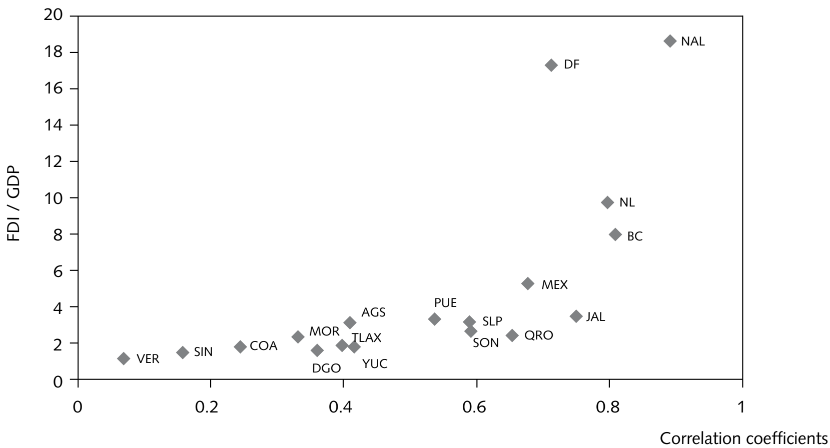
[18] In addition, some studies have found that the sunk costs of becoming an exporter are quite high, with smaller continuation costs of exporting (see Sanghamitra, Roberts and Tybout, 2007). This implies that exporting can be easier for foreign firms than for domestic firms, especially the small ones.

Figure 4. Relationship between the ratio of exports to gross domestic product (X/GDP) and the cross correlation coefficients, 1997-2007



Source: Elaborated on the basis of the authors' own computations and data from INEGI (www.inegi.gob.mx) and Bancomext (2005).

Figure 5. Relationship between the ratio of foreign direct investment to gross domestic product (FDI/GDP) and the cross correlation coefficients, 1997-2007



Source: Elaborated on the basis of the authors' own computations and data from INEGI (www.inegi.gob.mx) and Secretaría de Economía (www.economia.gob.mx).

tive association can be observed in both figures, even if we drop the "extreme" cases of Baja California (figure 4) and the Federal District (figure 5).[19]

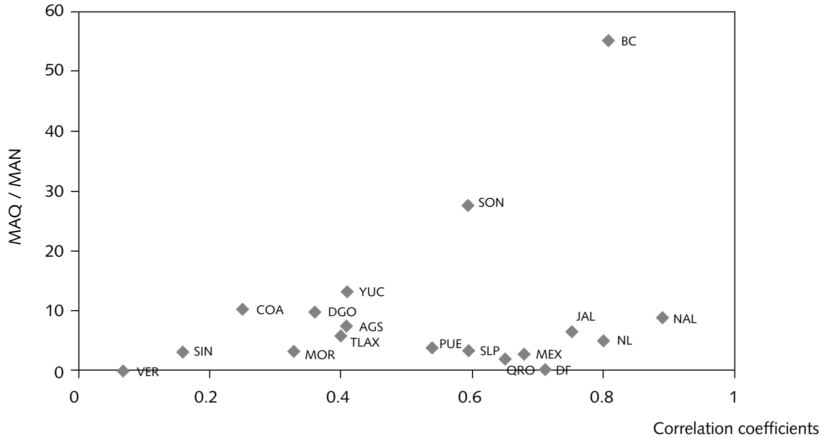
In turn, several papers have documented the importance of US off shoring activities in Mexico and the high sensitivity of the Mexican "maquila" production to the US economic fluctuations (see Acevedo, 2002; Mejía, 2003c; Bergin, Feenstra and Hanson, 2008). Therefore, it seems to be the case that states where "maquilas" represent a significant proportion of manufacturing production are more exposed to the US business cycle. Figure 6 represents the relationship between the computed correlation coefficients and the ratio of "maquila" to manufacturing production for the Mexican states. There seems to be a positive association between these two variables, determined in particular by the states of Baja California and Sonora, where the participation of "maquilas" in the manufacturing production exceeds 50 and 25 per cent respectively.

Finally, similar productive structures seem to play a central role in international synchronization, due to the significance of common sector shocks. Although some evidence has been provided about the relevance of this feature in the case of the US industries and their Mexican counterparts (see Chiquiar and Ramos, 2004), our attention focuses on the importance of Mexico's highly synchronized activities in state manufacturing production. In that sense, Mejía, Gutiérrez and Pérez (2006b) argue that manufacturing production of divisions II (textile, clothing, footwear and leather manufacturing) and VIII (machinery and equipment manufacturing) are the most importantly synchronized with the US business cycle. Thus, figure 7 presents the relationship between the computed correlation coefficients and the share of these two divisions in the total manufacturing production of each state. A positive trend can be observed across the dispersion of the corresponding pairs of points. This evidence supports our conjecture about the importance of international firms in international trade and investment as the dominant transmission mechanism of US business cycle effects.

In summary, our conjecture is that international trade and "maquila" production developed by firms established in Mexico's states and associ-

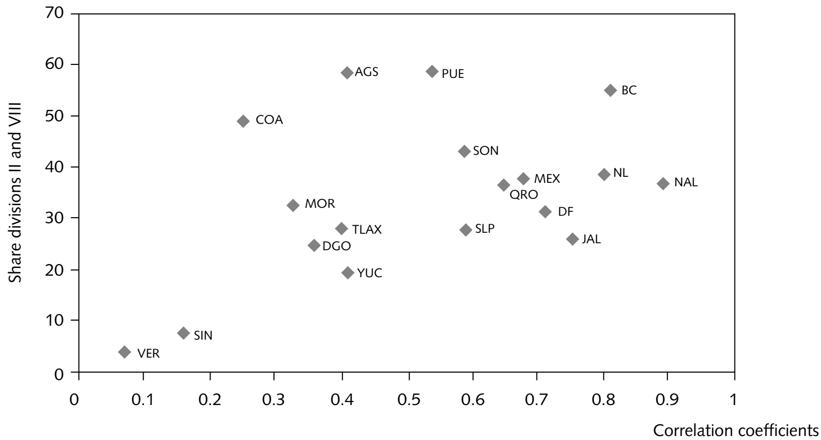
[19] For the former, the high value of the X/GDP ratio can be explained by the importance of the "maquila" exports, while for the latter the high FDI/GDP ratio reflects the lack of coincidence between the fiscal address of foreign firms and their physical plants. Notice that the figures represent the correlation coefficients computed with the HPC filter for the period 1997-2007. However, the results are robust with the other two detrending filters.

Figure 6. Relationship between the ratio of "maquila" to manufacturing production (MAQ/MAN) and the cross correlation coefficients, 1997-2007



Source: Elaborated on the basis of the authors' own computations and data from INEGI (www.inegi.gob.mx). *Note:* "Maquila" production is measured by the added value. The MAQ/MAN has been computed for the 1997-2006 period due to data availability.

Figure 7. Relationship between the share of divisions II and VIII in total manufacturing production and the cross correlation coefficients, 1997-2007



Source: Elaborated on the basis of the authors' own computations and data from INEGI (www.inegi.gob.mx). See the main text for further details. *Note:* Division II corresponds to textile, clothing, footwear and leather manufacturing, and Division VIII to machinery and equipment production.

ated with foreign capital –either of foreign property or vertically integrated to their productive processes– can explain international synchronization at this aggregation level.

Conclusions

Different papers claim that specific regional business cycles can differ from the national cycles and, consequently, react in a different manner to economic shocks, particularly those associated to external demand. According to the literature, common shocks and international transmission of domestic shocks, among others, can explain the synchronization of international business cycles. The Mexican economy has recently become very open and highly integrated to the international flows of trade and investment, as a consequence of the liberalization process started in the mid-80s. In fact, several papers have particularly documented a high synchronization between the Mexican and the US business cycles. However, some other papers have called the attention on the possible existence of heterogeneity in this process across sectors and regions of the Mexican economy, and to the need of further analyzing those differences to determine which activities are really integrated to the external sector, and where they are located.

In this framework, we analyze the degree of synchronization between the cycles of seventeen Mexican states and the US business cycle by using a growth cycle approach (Kydland and Prescott, 1990) for the period 1993-2007, although more emphasis is devoted to the 1997-2007 subsample, which excludes the effects of the mostly idiosyncratic 1995 recession. These states are the most important producers of manufactures and have different degrees of international integration, as measured by the magnitude of their exporting activities and the FDI attracted. Thus, different levels of synchronization to the US business cycle are expected for these specific Mexican cycles.

The business cycle indicators are obtained from seasonally-adjusted monthly manufacturing production indexes, given that several papers have reported a higher degree of synchronization for this output measure, and due to data availability. The robustness of our results is evaluated by using three different de-trending methods, namely the corrected version of the Hodrick and Prescott's (1997) filter introduced by Ravn and Uhlig (2002) and the Christiano and Fitzgerald's (2003) band-pass filter, as well as the annual growth rate. Our results confirm that the Mexican aggregate cycle is highly synchronized with the US business cycle. However, although specific Mexican state cycles are pro-cyclical with respect to the US business cycle, their synchronization is very heterogeneous. In particular, the synchronization is strong and robust only for the states of Baja California, Jalisco, Nuevo León and the Federal District, and at least moderate for Querétaro and the state of Mexico. Notice that the total share of these states in the national manufacturing production lies above three quarters, which suggests that their synchronization with the US business cycle explains that of the national aggregate. In turn, the synchronization is moderate and robust for another four states, Aguascalientes, Coahuila, Puebla and San Luis Potosí. Along with the literature, these results may be explained by the international linkages of the state manufacturing production associated with high volumes of exports in the case of traditionally industrialized states (Jalisco, Puebla, Nuevo León, the state of Mexico and the Federal District, which have experienced a deep transformation of their productive structures), and those newly industrialized (Querétaro, Aguascalientes and San Luis Potosí). In turn, the "maquila" production has been fundamental in the synchronization of Northern states (Baja California, Sonora and Coahuila). It is important to underline that in both cases the synchronization with the US business cycle has been conditioned by the specialization of the manufacturing sector and the participation of foreign firms.

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Appendix 1. Cross correlation between the Mexican states and the US business cycles, 1993-2007

State	*Contemporaneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads / lags*
		Corrected Hodrick-Prescott Filter			
BC	**0.77**	**Pro**	**0.77**	**contemp**	**0**
NL	*0.66*	*Pro*	*0.69*	*lags*	*2*
JAL	*0.66*	*Pro*	*0.68*	*lags*	*1*
MEX	*0.51*	*Pro*	*0.53*	*lags*	*3*
DF	*0.65*	*Pro*	*0.67*	*lags*	*1*
QRO	*0.61*	*Pro*	*0.66*	*lags*	*4*
SLP	*0.51*	*Pro*	*0.59*	*lags*	*3*
SON	*0.58*	*Pro*	*0.60*	*leads*	*5*
DGO	*0.43*	*Pro*	*0.61*	*lags*	*9*
PUE	*0.51*	*Pro*	*0.59*	*lags*	*4*
YUC	0.40	Pro	0.42	leads	1
AGS	0.37	Pro	0.43	leads	4
COAH	*0.23*	*Pro*	*0.55*	*lags*	*9*
MOR	0.37	Pro	0.37	contemp	0
TLAX	0.40	Pro	0.44	lags	6
SIN	0.10	Pro	0.15	leads	6
VER	0.06	Pro	0.13	leads	3
National	**0.71**	**Pro**	**0.73**	**lags**	**1**

Appendix 1. Cross correlation between the Mexican states and the US business cycles, 1993-2007 (continuation)

State	*Contemporaneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads / lags*
		Christiano-Fitzgerald Filter			
BC	**0.74**	**Pro**	**0.75**	**leads**	**1**
NL	**0.57**	**Pro**	**0.70**	**lags**	**4**
JAL	**0.61**	**Pro**	**0.75**	**lags**	**5**
MEX	0.33	Pro	0.45	lags	5
DF	*0.59*	*Pro*	*0.69*	*lags*	*4*
QRO	*0.50*	*Pro*	*0.66*	*lags*	*5*
SLP	*0.49*	*Pro*	*0.63*	*lags*	*5*
SON	*0.55*	*Pro*	*0.63*	*leads*	*4*
DGO	*0.29*	*Pro*	*0.60*	*lags*	*9*
PUE	*0.44*	*Pro*	*0.62*	*lags*	*6*
YUC	0.41	Pro	0.44	lags	3
AGS	*0.47*	*Pro*	*0.52*	*leads*	*3*
COAH	**0.13**	**Pro**	**-0.71**	**leads**	**9**
MOR	0.19	Pro	0.38	lags	9
TLAX	0.19	Pro	0.36	lags	9
SIN	0.35	Pro	0.36	leads	2
VER	0.08	Pro	-0.36	lags	9
National	*0.62*	*Pro*	*0.69*	*lags*	*3*

Appendix 1. Cross correlation between the Mexican states and the US business cycles, 1993-2007 (continuation)

State	*Contempo-raneous coefficient*	*Cyclicality*	*Maximum coefficient*	*Direction*	*Leads / lags*
			Annual growth rates		
BC	**0.72**	**Pro**	**0.72**	**contemp**	**0**
NL	*0.49*	*Pro*	*0.63*	*lags*	*2*
JAL	*0.46*	*Pro*	*0.58*	*lags*	*3*
MEX	0.35	Pro	0.44	lags	3
DF	*0.55*	*Pro*	*0.65*	*lags*	*2*
QRO	**0.59**	**Pro**	**0.70**	**lags**	**2**
SLP	0.29	Pro	0.49	lags	4
SON	0.44	Pro	0.46	contemp	0
DGO	0.35	Pro	0.46	lags	9
PUE	0.33	Pro	0.48	lags	6
YUC	0.27	Pro	0.35	lags	3
AGS	0.44	Pro	0.44	contemp	0
COAH	*0.24*	*Pro*	*0.56*	*lags*	*7*
MOR	0.20	Pro	0.22	leads	3
TLAX	0.32	Pro	0.40	lags	6
SIN	0.01	Pro	0.09	leads	9
VER	0.22	Pro	0.23	leads	3
National	*0.58*	*Pro*	*0.68*	*lags*	*2*

Source: Authors' own computations. *Note:* A strong (moderate) synchronization is indicated in bold (cursives). The states have been ordered according to the maximum correlation coefficient computed for the HPC detrended series in table 2. The same order is kept in this appendix.