

THE SENSITIVITY OF THE PUERTO RICAN ECONOMY TO UNITED STATES BUSINESS CYCLES: A SPECTRAL ANALYSIS

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Introduction

The unique political association between Puerto Rico and United States has given rise to an integral economic relationship between the two countries. This relationship over time has strengthened significantly to the extent that the economy of Puerto Rico is not only highly dependent on that of the U.S. but also has become somewhat sensitive to its business cycles particularly in the areas of commercial flows, unilateral transfer payments, and the movement of both capital and labor.

The issue of Puerto Rico's sensitivity to the U.S. business cycles, although somewhat difficult to determine due to the lack of a precise measure and suitable data, has been studied by several economists among whom, rank prominently, W. Baer (1962), J. Alameda and C. Rivera-Galindo (1976), Ruiz (1976-77), A. Ayuso (1982), and J. Alameda, I. Rivera and A. Rodríguez (1988). Most of these studies examined the lead-lag relationship in business cycles between both countries using a variety of statistical techniques as a measure of the degree of sensitivity. None so far however employed spectral analysis which constitutes the principal medium of measurement utilized in this study.

Spectral analysis although not a very precise measure, can be considered a more appropriate technique to those used in previous studies, since it can determine, to a large extent, the relative strength of a cycle with a certain fixed frequency or cycle length. Moreover, the use of cross spectral analysis permits the determination of the degree of association and timing between cycles with the same length in different time series. It is

particularly useful when two time series are analyzed together since their cross-spectra actually show the relation between their corresponding cycles.

In attempting to determine the sensitivity of Puerto Rico's economy to that of the U.S. and facilitate its analysis, business cycles in both economies were measured by two Coincident Composite Indexes: (1) the Index of Four Roughly Coincident Indicators developed by the United States Department of Commerce, and (2) the Index of Economic Activity prepared by the Planning Board of Puerto Rico. A complementary analysis is also made with the aim of determining the degree of association between manufacturing employment in Puerto Rico and the Index of Industrial Production in the United States.

Review of Previous Studies

As mentioned previously, several economists have studied the degree of sensitivity of the Puerto Rican economy to business cycles in the United States. Werner Baer (1962) in a seminal study found that the 1952-53 and the 1957-58 recessions had a mild impact on the economy of Puerto Rico and this led him to state:

...the two Mainland recessions in the 1950's revealed a very mild reaction on the island. The 1953-54 recession was mainly felt through a substantial decline in net migration, thus causing a rise in unemployment. In the 1957-58 period the recession was passed on mainly through a widespread production curtailment of older firms in the export industries.

The two major reasons for this mild impact, according to Baer were: (1) a sizable expansion in the establishment of new plants promoted by the Economic Development Administration of Puerto Rico which resulted in a rather stable level of employment and exports to the U.S. despite the weakening of its economy during the two recessions, and (2) the considerable reliance on the structural composition of exports heavily biased towards traditional agricultural products, generally characterized as having a low income-elasticity of demand. Despite the mild impact of these two recessions, Baer still affirmed that, even in the absence of a strong tendency in economic growth, as well as changes in commodity export composition emphasizing mainly manufactured products, the economic fluctuations in the United States would still be sharply felt in the economy of Puerto Rico.

J. Alameda and C. Rivera Galindo (1976), in a cross-sectional study, analyzed the impact of three U.S. recessions (1960-61, 1969-70, 1973-75) on the manufacturing sector of Puerto Rico, and found a slight decrease in hours worked during the first two recessions, while in the third, a rather severe reduction was noted. Their analysis also pointed out the increasing sensitivity of the Puerto Rican economy to these recessions, in terms of hours worked between workers employed in both countries.

A. Ayuso (1982) using a Vector Autoregressive Regression (VAR) model, and data covering a period of twenty-six years (1952-78), studied the effects, via employment multiplier, of several economic variables such as average wage-rates, material prices and aggregate output, on some manufacturing industries both in the U.S. and Puerto Rico. The results of this study, as shown in Table 1, indicate that innovations resulting in sudden changes in material prices, average wage-rates, and manufacturing output in the U.S., appear to have a stronger negative impact on the manufacturing sector of Puerto Rico than its counterpart on the mainland. Among the three variables, the effect of changes in wage-rates was more pronounced in the industries studied. Because of this Ayuso stated:

The Puerto Rican series exhibit a great deal of interrelationships with the United States series. In particular, the United States input factor prices account, between the two, for about 86% of the Puerto Rican manufacturing employment forecast error variance at the 32 quarters horizon.

Ayuso also compared Puerto Rico's multipliers with those of Canada, another open economy highly dependent on the United States. The results as shown on Table 2, indicate that changes in U.S. wage-rate and material prices, resulted in a more severe negative impact on the manufacturing sector of Puerto Rico, than in Canada. Actually the impact in Puerto Rico, apart from aggregate output, was more than double with respect to wage-rates and seven time greater in terms of material prices, in comparison to Canada.

TABLE 1

**MANUFACTURING EMPLOYMENT RESPONSES TO U.S.
INNOVATION: PUERTO RICO AND CANADA**

U.S. Innovation in:	Horizon Quarters	Employment Response in:		
		(1) Canada	(2) Puerto Rico	(3) Ratio (2)/(1)
Average Wage	32	-0.331	-0.917	2.77
Material Prices	32	-0.045	-0.325	7.22
Aggregate Output	8	+0.578	+0.716	1.24

Source: Ayuso A., The Transmission of Fluctuations from the Continental United States to Puerto Rico: A Manufacturing Microeconomic Approach with Weakly Specified Distribution, Ph.D. Dissertation, University of Minnesota, 1984. Table 4.4, page IV-18.

TABLE 2

VAR MULTIPLIERS FOR THE MANUFACTURING EMPLOYMENT
IN PUERTO RICO AND UNITED STATES

Industries	Innovation in U.S. variables	Employment Multipliers in Puerto Rico	United States
Apparel	Material Prices (+)	-0.472	-0.134
	Average Wage (+)	-1.540	-0.457
	Manufacturing Output (-)	0.661	0.550
Textiles	Material Prices (+)	-0.222	0.062
	Average Wage (+)	1.660	-0.590
	Manufacturing Output (-)	0.802	0.605
Stone, Clay, and Glass	Material Prices (+)	-0.013	0.050
	Average Wage (+)	-1.020	0.012
	Manufacturing Output (-)	0.661	0.535

All rows are defined in term of U.S.

(+) Response over a 32 quarters horizon. It also means above trend under one standard error positive innovation.

(-) Response over a 6 quarters horizon. Responses below trend.

Source: Ayuso, A., The Transmission of Fluctuations from the Continental United States to Puerto Rico: A Manufacturing Microeconomic Approach with Weakly Specified Lag Distribution, Ph.D. Dissertation, University of Minnesota, 1982. Table 5-4, page V-47.

The study by J. Alameda, I. Rivera and A. Rodríguez (1988) also demonstrated an increasing sensitivity of Puerto Rican economy to the recessions occurring in the United States. In this study three indexes of aggregate economic activity, and one index of total employment for the Puerto Rican economy were analyzed. Analysis of the results indicated that, the 1981-82 recession of the United States, had the most severe impact in the contemporary economic history of Puerto Rico. This severity was attributed to: (1) a reduction of Puerto Rico's economic growth trend between the late 1970's and early 1980's, (2) a shift in manufacturing employment from non-durable to durable goods, (3) a shift in manufacturing exports to United States based predominantly on capital goods, and chemical and analogous products, and (4) an increasing cyclical response of employment in the service sector during the 1970's and the inception of the 1980's.

In another study prepared by the Puerto Rico Planning Board and published in the **1987 Economic Report to the Governor**, cyclical elasticities were estimated (Table 3) to determine the impact of recessions and expansions in the United States on the Puerto Rican economy. This table shows that cyclical elasticities of U.S. recessions increased between 1973-82. On the other hand, the elasticities associated with expansions declined between 1961-78 and thereafter, increased during the eighties.

TABLE 3

**CYCLICAL ELASTICITIES OF THE PUERTO RICAN ECONOMY
TO UNITED STATES ECONOMY**

Recessions	Cyclical Elasticity	Expansions	Cyclical Elasticity
		1961-70	0.910
1973-75	0.641	1970-73	0.630
1978-82*	0.802	1975-78	0.390
		1982-19	0.631

*Timing for this recession in Puerto Rico differs from the recession in United States.

Source: Puerto Rico Planning Board, 1987 Economic Report to the Governor, Bureau of Economic Analysis, 1988.

An Overview of Spectral Analysis

Generally, spectral analysis attempts to show how total variance (power) is decomposed over a group of frequencies or corresponding cycle-lengths. An integral element of spectral analysis is spectral density, which is designed to determine the relative strength of cycles with frequency (F) or length ($1/F$). For instance, if a 100-month cycle is present in a series, the spectral density will depict a concentration of power - a density peak - with frequency bands $1/100$ cycle per year. Theoretically, the density assumes that the observed series are stationary, and trend-free in mean and variance. In reality, many economic time series normally do not satisfy the stationary condition, and consequently are considered non-stationary in presenting a strong positive trend and possibly infinite variance. However, it is possible, using a variety of techniques, to reduce this non-stationary aspect, by eliminating the trends before the estimation of spectral density is made. Some of these techniques include first, second, and third differences, percentage changes, quasi-differences, and differences of the logarithms of the original series. Actually, the different techniques have given rise to different conclusions in the process of economic analysis, and consequently resulted in a variety of economic policies.

In this study, cross-spectral analysis was used to determine the nature of the relationship between two series of equal length, and of a given frequency, represented by the following equation:

$$C_y (F_t) = A (F) C_x (F_t + Ph (f)) \quad (1)$$

where C_y is the cycle in the crossed series Y; C_x is the cycle in the base series X; $A (F)$ is the gain in amplitude; and $Ph (F)$ is the phase shift. Conventionally, economists support the idea that equation (1) can be thought of as a regression equation, in which $A (F)$ is analogous to the slope or regression coefficient, and $Ph (F)$ to the intercept.

From cross-spectral analysis some relevant statistical measures such as the coherence, gain, and tau can be derived. The coherence, which is analogous to the coefficient of determination (R^2) in regression analysis, measures the degree of association between two time series at a given frequency of cycle-length and can vary from one to zero. The higher (lower) the coherence value, the closer (lesser) is the degree of association

between the two series, at a given frequency or cycle-length. The gain is the ratio of the amplitude of the crossed-series cycles to its base-series cycles.

The tau statistic, is used to indicate the leads or lags of the two series measured in terms of real time and can be expressed as:

$$\tau = \frac{Ph}{2\pi F} \quad (2)$$

where Ph is the phase angle (in radians) and F , the frequency. When τ is positive, the base-series leads the crossed-series and when τ is negative, the base-series lags the crossed-series. Nonetheless, House (1971) has demonstrated that the application of τ of the phase angle to the lead-lag relationship in economics can be misleading and consequently, may have limited application with respect to business cycles.

Results and Interpretations

The data utilized in this study covers the period of January 1970 to December 1987. As mentioned previously analysis is based using two main coincident composite indexes, the Index of Four Roughly Coincident Indicator of United States, and the Index of Economic Activity of Puerto Rico.

Because of the close relationship of manufacturing employment between Puerto Rico and the United States manufacturing employment was crossed with the U. S. Index of Industrial Production. A first difference method was applied to all time series in order to eliminate the trend. This conversion is equivalent to removing a linear trend. The estimation of spectral density was performed by smoothing the period gain by means of Daniel Filters of four half-lengths.

The statistical results are shown in Tables 4 and 5 and for all cycle-lengths (between infinite trend to two months). On the basis of these results, it is evident a strong linear association exists between the Puerto Rican economy and that of the United States. This means that Puerto Rico's short and long term (duration) economic cycles move very closely with their counterparts in the United States. The results also suggest that cycles in Puerto Rico of lengths between 10 to 256 months are strongly correlated with United States cycles of similar lengths. In particular, cycles

ranging from 40 to 50 months in length depict significant coherence coefficient values.

On the other hand, Puerto Rico's manufacturing employment cycles are also highly correlated with U.S. industrial production cycles specifically those ranging from 15 to 256 months. As in the previous case, cycles between 40 to 50 months tend to show the highest significant coherence coefficient values. Actually about 90 percent of the variation in Puerto Rico economic cycles of this length, can be explained by the U.S. economic cycles of the same length. The remaining 10 percent obviously can be attributed.

The interpretation of the statistic tau or the phase angle is somewhat more difficult. There does exist some ambiguity in the interpretation of the phase angle as a negative or positive delay at a given frequency (see explanations in House (1971), and Fishman (1968)). Nonetheless, interpretation of tau must be undertaken with some knowledge about the structural or observable relationship between the two time series studied.

Empirical evidence strongly suggest that the Puerto Rican economy tends to lead the United States economy, although the timing is extremely close. Tau sign results for given frequencies are consistent with this fact. Puerto Rico appears to lead the United States by less than one month, in cycle-lengths of 40 to 50 months. Since the smallest of unit time considered here is a month, tau value of -0.8 implies that lead-lag relationship between both economies tend to more almost together in cycles of similar lengths. In cycle-lengths between 28 to 256 months, Puerto Rico however appears to lead the United States by one to two months. This is a significant result since a previous study by Baer showed that Puerto Rico lagged the United States economy between six to nine months during the 1950's.

On the other hand, Puerto Rico manufacturing employment showed in general terms, a lagged relationship with the United States industrial production. This statement is also confirmed by the empirical evidence. This lag relationship is more notable in cycle-lengths of 26 to 256 months where it can range from about one to four months.

TABLE 4
RELATIONSHIP BETWEEN THE PUERTO RICO BUSINESS
CYCLES AND UNITED STATES BUSINESS CYCLES*

Frequency or cycle-length (in Months)	Coherence	Tau (in Months)
infinite (trend)	.88	0.0
256	.88	-2.2
128	.87	-0.6
85	.89	-0.8
64	.88	-0.8
51	.90	-0.8
43	.91	-0.8
37	.89	-1.1
32	.83	-1.0
28	.79	-0.3
26	.76	+0.06
23	.75	+0.50
21	.76	+0.80
18	.70	+1.5
17	.65	+1.0
16	.66	+0.36
15	.60	-0.03
14	.55	-0.20
13-12	.23	+0.12
11.1	.54	+1.3

Table 4 Cont.

10.2	.56	+0.9
8.0	.15	+0.4
7.1	.45	-0.003
5.0	.30	-0.57
3.0	.16	-0.36
2.0	.35	-0.17

* Base series: U.S. Index of Four Roughly Coincident Indicator, January 1970 to December 1987.

Crossed series: Index of Economic Activity, January 1970 to December 1987.

TABLE 5

**RELATIONSHIP BETWEEN PUERTO RICO MANUFACTURING
EMPLOYMENT AND UNITED STATES
INDUSTRIAL PRODUCTION**

Frequency or cycle-length (in Months)	Coherence	Tau (in Months)
infinite (trend)	.79	-0.0
256	.79	+3.5
128	.82	+3.7
85	.85	+2.4
64	.88	+1.4
51	.92	+1.0
43	.94	+1.0
37	.91	+0.9
32	.86	+1.0
28	.85	+1.1
26	.81	+1.1
23	.79	+0.9
21	.81	+0.6
18	.68	+0.1
17	.74	-0.3
16	.80	-0.7
15	.53	-0.32
14	.36	-0.06
13-12	.24	+1.2

Table 5 Cont.

11.1	.30	+1.3
10.2	.28	+1.3
8.0	.07	-0.3
7.1	.28	-0.6
5.0	.18	-0.1
3.0	.08	-0.09
2.0	.07	-0.02

* Base series: U.S. Index of Industrial Production, January 1970 to December 1987.

Crossed series: Puerto Rico employment manufacturing, January 1970 to December 1987.

Conclusions

This paper analyzed the degree of sensitivity of Puerto Rico's economic cycles to those of the United States. Analysis was based on the cross-spectral technique, using monthly data for the period January 1970 to December 1987. The Index of Economic Activity was used as a measure of Puerto Rico's business cycles, while the Index of Four Roughly Coincident Indicators was used, for similar cycles in the United States.

The statistical results indicate a strong degree of association or coherence between Puerto Rico's business cycles and those of United States. For cycles between 40 to 50 months duration, slightly more than 90 percent of the variation in Puerto Rican economic cycles can be accounted for by variation in the United States cycles. The other 10 percent can be attributed to accounted or by endogenous forces in Puerto Rico or other exogenous factor.

The results also point out a strong association between cycles in Puerto Rico's manufacturing employment and the U.S. industrial production. For cycles between 40 to 50 months of duration in Puerto Rico manufacturing employment, more than 92 percent of its variation can be explained by U.S. industrial production.

The lead-lag relationship for both economic cycles was also examined by tau sign and confirmed by the empirical evidence. Statistical results, combined with the evidence, suggest that the Puerto Rican economic activity appears to move almost coincidentally with the U.S. economic cycles. For a long-cycle duration (256 months), Puerto Rico appears to lead United States by two months. Conversely, Puerto Rico manufacturing employment appears to lag the U.S. industrial production by one to four months for cycles with duration greater than 40 months.

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APPENDIX

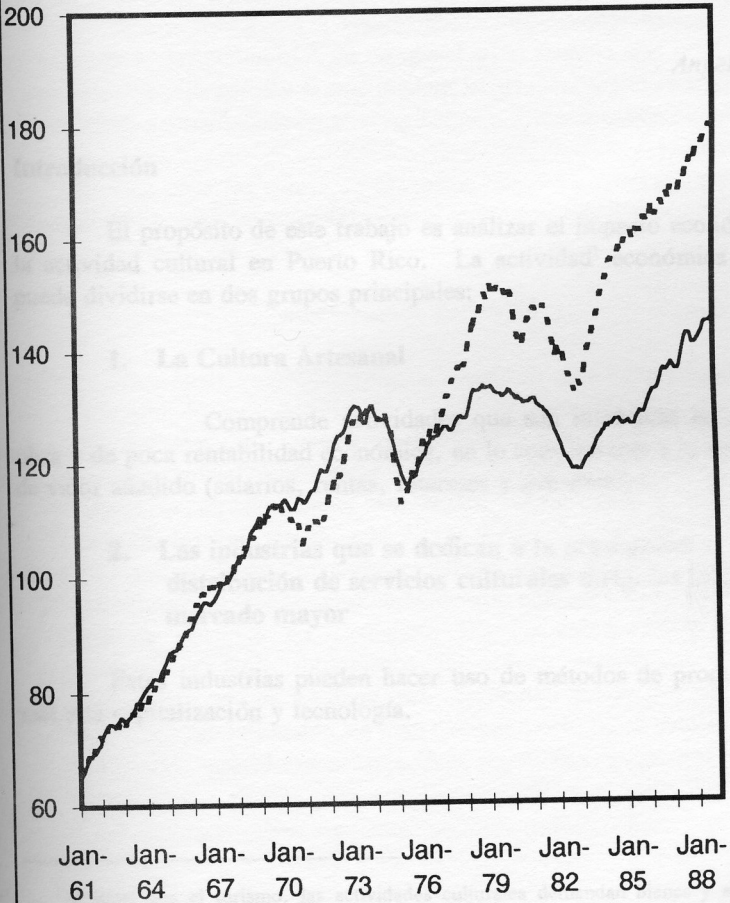
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Business Cycle in Puerto Rico and United States



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