The Transmission of Economic Fluctuations from
United States to Puerto Rico, 1950 to 2019:
Real and Monetary Shocks

This paper revisits the topic of the role of real and monetary factors in economic fluctuations. The issue is examined by observing the responses of Puerto Rico’s economy to both types of shocks originating in the United States. The case of Puerto Rico is studied because it is an excellent example of an open economy, given the strong economic and political ties between itself and the United States. The technology shocks were identified using the methodology proposed by Galí (1999) applied to U.S. data, while M2 was utilized as the sources of monetary disturbances. The empirical analyses suggest that technological shocks are important for Puerto Rico’s real aggregate production dynamics. These shocks explain very well the annual rate of growth of Puerto Rico’s GNP from 1965 to 1990. After this date, the capacity of these two shocks in explaining Puerto Rico fluctuations diminished drastically. On the other hand, there was no substantial evidence of the relevance of monetary shocks in the Puerto Rico business cycle.

Keywords: Technological Shocks, Monetary Impulses, Business Cycle, Puerto Rico

JEL: C22 E32, E52

Introduction

There is a renewed interest in the business cycle study after the financial crisis that generated the Great Recession in the years 2007 and 2008 in the United States and other countries. One relevant point is the identification of the principal driver of economic fluctuations. There is a debate associated with different schools of macroeconomics thought. From the 1980s to the present, the main controversy is between the real business cycle (RBC) theories that stress the role of technology shocks in the business cycle and other schools that state that aggregate demand shocks, principally monetary, are the more relevant impulses in this phenomenon.

In this paper, this issue is revisited using data from Puerto Rico. This paper's objective is to investigate some aspects of the business cycle phenomenon in an open economy. In this type of economy, it is relevant to examine local and imported shocks' sources. The case of Puerto Rico is studied because it is an excellent example of an open economy with strong economic and political ties with the United States and Puerto Rico. Hence, there are several transmission channels from the economy of the United States to the country: for example, the bilateral trade between both countries, the financial markets, and the manufacturing sector of the island that includes U.S. high technology industries.

Furthermore, the island economy has certain characteristics that help shed some new light on the debate on the causes of the business cycle. First, the
economic structure of the island is different from the U.S. economy, so new information to analyze the issue is added. Second, Puerto Rico does not regularly use contra-cyclical economic policies that may interfere with the impact of the perturbations under analysis, allowing for proper identification of the impulses' impacts. Third, the analysis of the external shocks avoids the endogeneity problems that, for the case of money, were first pointed out by Tobin (1970). Finally, the island has experienced several recessions in the last decades, so the economic activity data has enough variability to allow for the econometric estimation with a certain level of accuracy.

Two specific issues are examined in this paper: First, are the economic fluctuations in Puerto Rico the result of local or U.S. economy perturbations? And, second, what is the relative importance of real and monetary factors in producing deviations of Puerto Rico's economy from its steady-state? A four variables Structural Vector Autoregressive (SVAR) model, with long-run restrictions, is estimated to examine these issues. The results of this paper constitute a contribution to the literature of the business cycle as well as to the understanding of the dynamics of the economic activity in Puerto Rico.

**Literature Review**

In this section, a sample of the more relevant papers of business cycles related to the theme of this paper is discussed. After some decades of being forgotten, the resurgence of interest in the business cycle phenomenon began with Lucas (1975), where a competitive equilibrium business cycle model was presented. This model has the characteristic that economic fluctuations are seen as optimal responses of the economic agent to changes in the state of the economy. In Lucas's model, money is the principal source of economic fluctuations.

The real business cycle (RBC) theories developed in the 1980s following the seminal works of Kydland and Prescott (1982). These authors presented a model of general equilibrium, characterized by the existence of technological shocks and various propagation mechanisms that reproduce the behavior of the United States' economic activity in the post-war period. According to the authors, the model explains more than half of the fluctuations in the United States economy in that period, without monetary shocks. This paper was extended by Long and Plosser (1983), who present an aggregate model that was able to explain the joint movement of productions from different economic sectors. The authors reached the same conclusion of Kydland and Prescott: innovations in real variables generate the economic fluctuations, leaving very little room for monetary impulses. An additional point in favor of these theories was raised by King and Plosser (1984), a point that explained the relationship of output-money with inside money. Manchester ( ) provided additional evidence for this point.

On the empirical side, Blanchard and Quah (1989) identified aggregate supply and aggregate demand shocks in a vector auto-regressive model,
estimated with quarterly U.S. data for the period 1950:2 to 1987:4. The impulses' response function of the system revealed that the two types of impulses generate economic fluctuations. However, the variance decompositions suggest that unexpected changes in aggregate demand have a more significant effect on production and unemployment than those associated with the aggregate supply. The authors interpreted this result as evidence against the RBC theory. Keating and Nye (1998) extended this using data from ten countries for the period 1869 to 1974. The results of Keating and Nye's analysis vary for some countries, but generally confirm Blanchard and Quah's findings that aggregate demand impulses are more relevant than those of aggregate supply, as technological shocks, in explaining economic fluctuations. Ahmed and Park (1992) contribute to this debate by distinguishing between external and local impulses and examining the relative importance of unexpected changes in aggregate demand and supply (AS). These authors' research used a data set from seven small and open economies from the OECD countries for the period 1960 to 1987. In the analyses, it was found that the fluctuations in aggregate output in these countries are mainly explained by local shocks associated with AS. The authors interpreted these findings as evidence in favor of the theory of real business cycles.

In an interesting paper, Galí (1999) uses long-run restrictions on a two-variable VAR system to econometrically identify technology shocks and other innovations that impact labor productivity and employment. This author uses quarterly data from the United States for the period 1948:1 to 1994:4 and the post-war period for the other G-7 countries. The response impulse functions of the system estimated by Galí revealed that technological impulses tend to increase productivity and reduce labor input. This last result is contrary to the RBC models. Similar findings were reported by Shea (1999) and Francis and Ramey (2001, 2002).

For the case of Puerto Rico, only a few authors examine this topic; some of their studies examine the role of local causes of economic fluctuations. Toledo (1994) found that real oil prices are more important than inside money in Puerto Rico's business cycle. The same author (Toledo, 2004) estimated that local supply impulses are slightly more important than demand shocks for medium and long-run real GNP dynamics, while Toledo (2006) does not find evidence of the importance of local technological shocks in the economic activity of the Island.

Another set of studies have taken into consideration the effects of United States' shocks on Puerto Rico's economy. For example, Alameda (1996) found that the Solow residual of the industrial production and M2, both of the United States, have little effect on the real aggregate production of Puerto Rico. Rodriguez and Toledo (2007), Toledo and Hernández (2014), and Rodriguez (2018) obtained evidence that the federal fund rate of the U.S. explains until a third of fluctuations of the real economic activity in Puerto Rico.
Data and Methodology

A four-variable VAR model was constructed to examine the topic posed in this paper. The system may be represented as:

\[
\begin{bmatrix}
\Delta \left( \frac{W}{P} \right)_{US,t} \\
\Delta L_{US,t} \\
\Delta M_{US,t} \\
\Delta Y_{PR,t}
\end{bmatrix} =
\begin{bmatrix}
\phi_{11}(L) & \phi_{12}(L) & \phi_{13}(L) & \phi_{14}(L) \\
\phi_{21}(L) & \phi_{22}(L) & \phi_{23}(L) & \phi_{24}(L) \\
\phi_{31}(L) & \phi_{32}(L) & \phi_{33}(L) & \phi_{34}(L) \\
\phi_{41}(L) & \phi_{42}(L) & \phi_{43}(L) & \phi_{44}(L)
\end{bmatrix}
\begin{bmatrix}
\Delta \left( \frac{W}{P} \right)_{US,t} \\
\Delta L_{US,t} \\
\Delta M_{US,t} \\
\Delta Y_{PR,t}
\end{bmatrix} +
\begin{bmatrix}
\epsilon_{1,t} \\
\epsilon_{2,t} \\
\epsilon_{3,t} \\
\epsilon_{4,t}
\end{bmatrix}
\]

(1)

Where \( \frac{W}{P} \) is the real wage (a proxy for labor productivity), \( L \) is aggregate employment, \( M \) is M2, \( Y \) is real GNP, \( \Delta \) is the first difference symbol, U.S. stands for the United States, and P.R. for Puerto Rico. All variables are in logarithms. The first differences were used because the variables are I(1). The first two variables are used to extract the technology shocks based on Gali (1999), while the monetary shocks come from M2. The real GNP is used as the economic activity indicator of Puerto Rico. The first two variables represent the equilibrium in the labor market \( (L = f \left( \frac{W}{P} \right)) \), while the monetary aggregate comes from the equilibrium condition of aggregate supply \( (YS) \) and demand \( (Y_d) \) \( (Y_s = g(P; W), \ Y_d = g'(P; M), \ \text{and} \ g(P; W) = g'(P; M)) \). Thus, it is possible to construct a structural model where the reduced form model (VAR) presented here can be derived; that action is beyond the scope of this paper.

The inclusion of Puerto Rico’s GNP implies that the U.S. shocks are potential sources of disturbances in the island economy.

System (1) may be represented in the vector moving average (VMA) representation, as:

\[
\begin{bmatrix}
\Delta \left( \frac{W}{P} \right)_{US,t} \\
\Delta L_{US,t} \\
\Delta M_{US,t} \\
\Delta Y_{PR,t}
\end{bmatrix} = \Gamma(L)
\begin{bmatrix}
\epsilon_{1,t} \\
\epsilon_{2,t} \\
\epsilon_{3,t} \\
\epsilon_{4,t}
\end{bmatrix}
\]

(2)

The structural shocks were identified with long-run restrictions. The following matrix shows the identification scheme:

\[
\Gamma(1) =
\begin{bmatrix}
y_{11} & 0 & 0 & 0 \\
y_{21} & y_{22} & 0 & 0 \\
y_{31} & y_{32} & y_{33} & 0 \\
y_{41} & y_{42} & y_{43} & y_{44}
\end{bmatrix}
\]

These restrictions imply: there is a type of shock that has permanent effects on all the systems’ variables (technology shocks), there is a disturbance
that in the long-run impacts M2 and Y, but not \( \frac{W}{p} \) (non-technological disturbances), the Puerto Rico aggregate production's shocks do not impact the other variables permanently, M2 does not have permanent impacts on the United States labor market variables but can affect Puerto Rico's real output in the long-run.

Thus, there are two U.S. labor market real shocks, one monetary shock, and a Puerto Rico local shock. This methodology will allow us to determine the relative importance of these shocks generating oscillation in Puerto Rico economics' activity.

The model was estimated in a data set of annual data from 1950 to 2019 was used. The United States data is from the Federal Reserve Economic Data (FRED) of the Federal Reserve Bank of St. Louis. The GNP of Puerto Rico comes from the Puerto Rico Planning Board. Some dummy variables were added to the system to model structural changes.

**Results and Discussion**

The model was estimated using three lags as determined by the Akaike Information Criterion. The residual of the model is white noises, and the system is stable. The system's dynamic response to exogenous shocks is examined using the impulse response functions, the forecast error variance decomposition, and the historical decomposition. The impulse response functions are calculated using the moving average representation of the model. For example, the first difference of Puerto Rico real GNP (\( \Delta Y_t \)) the moving average representation is expressed as:

\[
\Delta Y_t = \sum_{i=1}^{n} B_i Z_{t-i}
\]

In this representation, \( B \) is the dynamic response of \( \Delta Y_t \) to the disturbances in the system, while \( Z \) contains the four variables' innovations. The observed shocks are taken as positive residuals of one standard deviation magnitude for each of the five variables. The impulse response functions' responses of \( \Delta Y_t \) to the U.S. technology and monetary shocks are presented in Figure 1 and 2. Both shocks generate fluctuations in the real GNP of Puerto Rico that resemble the business cycle phenomenon.

The initial effect of the technological impulses on real GNP is negative, but quickly become positive for a couple of periods. After the fourth period, this perturbation negatively impacted Puerto Rico's economy until it converged to zero. It is evident that only the positive response of aggregate output for this class of disturbances is statistically different from zero at a confidence level of 95%. On the other hand, the impact of monetary shocks on Puerto Rico's real GNP is not statistically distinct from zero in all the periods. The average response to this class of shocks is mostly negative.

To summarize, the impulse-response functions results provide evidence that fluctuations in the U.S. economy are transmitted to the Puerto Rican
The analysis mentioned above shows that real (technological) shocks seem to be more important for the Puerto Rico economic activity than monetary shocks. The forecast error variance decomposition function (FEVD) is examined to explore this point more deeply. The FEVD determines how much of the forecast error variance of each of the variables in the model can be explained by exogenous shocks to the other endogenous variables in the system. Thus, this tool is important to determine the relative importance of each shocks’ source in the variable of interest dynamics.

The principal feature of interest in the variance decomposition, reported in Table 1, is the importance of Puerto Rico’s local shocks in explaining the movement of the rate of growth of the real GNP of the island, in the short run,
and the U.S. labor impulses in the long run. For example, in the first forecast quarter, the local shocks explain close to 90% of the forecast error variance of real aggregate production in Puerto Rico. This percentage is reduced to 43% after five periods of the occurrence of the perturbation. In the fifth forecast horizon, the technological shocks explain 15% of GPP variation, while the non-technological impulses are responsible for 26% of this variation. The money shocks explain only about 5% of the Puerto Rico GNP variations at this forecast horizon. After ten periods of the shocks’ occurrence, the United States economic shocks are responsible for almost 58% of the FEDV of the economic activity of Puerto Rico.

Table 1. Decomposition of the Forecast Error Variance of Puerto Rico’s Real GNP (M2 does not have permanent impacts on the U.S. labor market variables)

<table>
<thead>
<tr>
<th>Forecast’s Horizon</th>
<th>Source of the Impulses:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Technology</td>
</tr>
<tr>
<td>1</td>
<td>1.9378</td>
</tr>
<tr>
<td>2</td>
<td>7.7189</td>
</tr>
<tr>
<td>5</td>
<td>16.2485</td>
</tr>
<tr>
<td>6</td>
<td>18.1953</td>
</tr>
<tr>
<td>10</td>
<td>18.7318</td>
</tr>
</tbody>
</table>

Historical Decompositions

Historical decompositions (H.D.) are useful to determine the proportion of the variables unconditional mean in each period that can be attributed to a particular structural shock. This unconditional mean can be taken as the steady-state of the variable. Therefore, the H.D. shows the impulses responsible for the deviation of the variables from its long-run trend. Figure 3 shows the historical decomposition of Puerto Rico’s real GNP from 1965 to 2015. As is evident in Figure 3, the technology-shocks explain the annual growth rate of Puerto Rico's GNP from 1965 to 1991 very well. The monetary shocks also follow the dynamic of the island's economic activity during the mentioned period, but this explains much less of it than the technology shocks. After 1990, the capacity of these two shocks in explaining Puerto Rico's fluctuations diminished. In contrast, the technology shocks (Figure 3) reasonably explain the deviation of Puerto Rico's real aggregate output from 1965 until 2000. After that date, the contribution of this type of shock in the displacement of this indicator from its steady-state reduced.
Robustness

Two more estimates were realized to check for the sensibility of the results to the model specification. First, the long-run restriction on the SVAR model was modified to allow M2 to have long-run effects on U.S. employment. This finding implies that the assumption of long-run money neutrality in the U.S. was relaxed. Table 2 contains the forecast error variance decomposition for this model. As is evident, the monetary disturbances explain a more significant proportion of the economic activity in Puerto Rico than in the former model. However, except for the second forecast horizon, the technological shocks are more important for the island business cycle than the monetary policy impulses, the same result as reported above.

Table 2. Decomposition of the Forecast Error Variance of Puerto Rico’s Real GNP (M2 has a permanent effect on U.S. employment)

<table>
<thead>
<tr>
<th>Forecast’s Horizon</th>
<th>Technology</th>
<th>Non-Technology</th>
<th>Monetary</th>
<th>Local</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.4405</td>
<td>9.41876</td>
<td>0.35414</td>
<td>89.7866</td>
</tr>
<tr>
<td>2</td>
<td>8.6538</td>
<td>23.3689</td>
<td>11.8164</td>
<td>56.1609</td>
</tr>
<tr>
<td>5</td>
<td>25.0111</td>
<td>20.2940</td>
<td>11.2727</td>
<td>43.4220</td>
</tr>
<tr>
<td>6</td>
<td>26.5614</td>
<td>20.0832</td>
<td>10.8994</td>
<td>42.4560</td>
</tr>
<tr>
<td>10</td>
<td>26.9704</td>
<td>19.8281</td>
<td>10.9365</td>
<td>42.2649</td>
</tr>
</tbody>
</table>

Second, a different two-step methodology was utilized. For the first step, a VAR model for the three economic indicators of the United States, with the original set of long-run restrictions, was estimated. From this system, the structural shocks were extracted. In the second step, Puerto Rico's real GNP was regressed on the first lag on each of these three structural shocks, and its first lag. Table 3 presents the results of the estimation of the one-equational
model. The independent variables explain about 77% of the variations in the
dependent variable. According to the Q-Statistic and White's Test, the model
does not exhibit autocorrelation or heteroscedasticity problems. As is evident
from these results, the technological shocks and non-technological shocks have
a significant positive effect on the economic activity of Puerto Rico, while the
coefficient of the monetary shocks variable is not statically different from zero.
These findings are consistent with the results reported in the previous sub-
section.

Table 3. Results of the Estimation of the Linear Regression Model of Real
GNP of Puerto Rico

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>Std. Error</th>
<th>t-Statistic</th>
<th>P-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>0.0114</td>
<td>0.0039</td>
<td>2.8651</td>
<td>0.0061</td>
</tr>
<tr>
<td>One Lag of Real GNP</td>
<td>0.6295</td>
<td>0.0898</td>
<td>7.0071</td>
<td>0.0000</td>
</tr>
<tr>
<td>Structural Change Dummy</td>
<td>-0.02043</td>
<td>0.0071</td>
<td>-2.8850</td>
<td>0.0058</td>
</tr>
<tr>
<td>One Lag of Monetary Shocks</td>
<td>-0.0027</td>
<td>0.0024</td>
<td>-1.1239</td>
<td>0.2665</td>
</tr>
<tr>
<td>One Lag of Technology Shocks</td>
<td>0.0051</td>
<td>0.0024</td>
<td>2.1513</td>
<td>0.0364</td>
</tr>
<tr>
<td>One Lag of Non-Technology Shocks</td>
<td>0.0102</td>
<td>0.0024</td>
<td>4.2485</td>
<td>0.0001</td>
</tr>
<tr>
<td>Diagnostic</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R-squared</td>
<td>0.7692</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjusted R-squared</td>
<td>0.7456</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>F-statistic</td>
<td>32.6570</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-Value of F</td>
<td>0.0000</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Section summary

The above analyses imply that monetary shocks are irrelevant for the
dynamics of the real aggregate production of Puerto Rico. This finding
coincides with Alameda (1996), who reported that M2 does not seem to affect
the Island's economic activity. Thus, if the monetary policy affects Puerto
Rico's economy is through the interest rate, as was found by Rodriguez y
Toledo (2007) and Rodriguez (2018), possibly via bank loans (see Toledo
(1997)). Hence, the money neutrality proposition cannot be discarded for
Puerto Rico, as it was found in a previous study M2 is cointegrated with the
island Price level (Toledo, 2002). Thus, the available evidence is that money
affects the price level and has little impact on real output in the Island.

On the other hand, with respect to the impacts of technology shocks, the
results discussed above coincide with Toledo (2006) that finds that local
technological shocks are important for Puerto Rico's real aggregate Production
dynamics. As this author discussed, many of the shocks that he identified
presumably came from the high-technology U.S. firms that operate on the
island.
Concluding Comments

This paper examined the transmission of economic fluctuation from the United States to Puerto Rico. Evidence was found that shocks to the U.S. economy are transmitted to the island economy. The principal sources of these fluctuations seem to be technological impulses. Innovations in technology adequately explain the deviation of Puerto Rico’s real aggregate output from 1965 until 2000; after that date, however, the contribution of this type of shock to the displacement of this indicator from its steady state decreased. The monetary shock, on the other hand, has little effect on Puerto Rico’s economic activity. Hence, the results of this investigation support the theory that real forces are the drivers of economic activity in the island.

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