

# ON THE ROLE OF TECHNOLOGY SHOCKS AS A SOURCE OF BUSINESS CYCLES: SOME NEW EVIDENCE

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## **Abstract**

I provide some new evidence that reinforces the conclusion in Galí (1999) that exogenous variations in technology play a very limited role, if any, as sources of the business cycle. First, I provide evidence that supports the identification of technology shocks proposed in that paper. Second, I show that similar findings obtain when the same approach is implemented for the Euro area, using a newly available data set. (JEL: E32, E24)

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## **1. Introduction**

The present paper revisits the empirical evidence on the role of technology shocks as a source of business cycles contained in my earlier work (Galí 1999). My main goal is to address some concerns that have been raised about the approach used in that paper and the interpretation of its findings. In doing so, I provide some new evidence that reinforces the main conclusion in Galí (1999), namely, that exogenous variations in technology play a very limited role, if any, as sources of the business cycle. In particular, I provide evidence that supports the identification of technology shocks proposed in that paper. Secondly, I show that similar findings obtain when the same approach is implemented for the Euro area, using a newly available data set. As I argue below, the latter finding is of special interest in light of the critique of Christiano, Eichenbaum, and Vigfusson (2003), given the time series properties of employment in Europe.

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## 2. Background

In Galí (1999) I sought to assess the role of technology shocks as a source of business cycles in the United States and the remaining G7 countries using a structural VAR, estimated on quarterly postwar time series. I identified technology shocks by means of a long run restriction under which only those shocks were allowed to have a permanent effect on (average) labor productivity. That assumption was argued to hold under relatively weak conditions, satisfied by a broad range of models, including RBC and New Keynesian ones. Among the empirical findings in Galí (1999) there is one that has drawn substantial interest and provoked some controversy: in response to a positive technology shock, measures of labor input were shown to decline, while GDP would adjust only gradually towards its permanently higher level.<sup>1</sup> Thus, and conditional on technology shocks as a source of fluctuations, labor input showed a negative correlation with output (or labor productivity).

The previous finding has several implications of relevance for business cycle analysis and modeling, which have been discussed in detail in Galí (1999) and the subsequent literature. Most significantly, those findings reject a key prediction of the standard RBC paradigm, for in the latter a positive comovement of output, employment and productivity in response to technology shocks lies at the root of its ability to generate fluctuations that resemble business cycles. A second implication follows as a corollary: variations in technology cannot have been a dominant source of observed business cycles, for the latter are characterized by a very strong positive comovement between output and labor input measures. That corollary applies independently of the paradigm that one believes may provide the best representation of cyclical fluctuations. Finally, Galí (1999) also pointed to the consistency of those findings with the predictions of sticky price models, as long as monetary policy was sufficiently less-than-fully accommodating in response to technology shocks.

The findings in Galí (1999) were corroborated in independent work by Basu, Fernald, and Kimball (1999), using a sophisticated growth accounting approach in order to identify technology shocks. Recent work by Francis and Ramey (2003), Galí, Lopez-Salido, and Vallés (2003), Fisher (2002), Uhlig (2003, 2004), and others has provided additional evidence supporting, qualifying, or calling into question the abovementioned findings.<sup>2</sup>

The present paper has two main objectives. First I try address a question that is often raised regarding the empirical approach used in Galí (1999): to what extent can we be confident in the economic interpretation given to the identified

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1. Japan provided an exception to that finding, for employment was estimated to rise in response to a positive technology shock in that country.

2. A survey of that literature, including a detailed discussion and comparison of the main findings, is forthcoming.

shocks and, in particular, in the mapping between technology shocks and the nonstationary component of labor productivity? An attempt to provide an answer to that question can be found in Section 3. The second objective is to extend the empirical analysis in Galí (1999) to the euro area, using the data set constructed by Fagan, Hanry, and Mestre (2001) and which has been recently updated. The evidence for the euro area, and a discussion of its implications for the controversy regarding the effects of technology shocks can be found in Section 4. Section 5 summarizes and concludes.

### 3. Interpreting VAR-Based Permanent Shocks as Technology Shocks

Suppose that technology can be described by an aggregate production function

$$Y = F(K, AN) \quad (1)$$

where  $Y$  denotes output,  $K$  is the capital stock,  $N$  is labor input and  $A$  is an index of technology. Under the assumption that  $F$  is homogeneous of degree 1, we can write

$$\frac{Y}{N} = AF(k, 1) \quad (2)$$

where  $k \equiv (K/AN)$  is the ratio of capital to labor (expressed in efficiency units). Let  $\tau$  denote the tax rate on capital income. For a large class of models the following equilibrium condition (or similar) must hold along a balanced growth path

$$(1 - \tau)F_k(k, 1) = \text{const.} \quad (3)$$

where the constant is typically a function of the time discount rate, the depreciation rate, and other exogenous parameters (generally assumed to be constant). As argued in Galí (1999) only shocks that have a permanent effect on  $A$  or  $k$ , can be a source of the unit root in labor productivity. If one ignores the possibility of permanent changes in the capital tax rate then only permanent technology shocks can have a permanent effect on productivity, thus providing the theoretical underpinning for the identification scheme in Galí (1999). However, as Uhlig (2004) and others have pointed out, the assumption of a stationary capital income tax rate may be unwarranted, given the large, seemingly permanent, shifts in measures of that variable over the postwar period. Accordingly, the shocks with permanent effects on productivity identified in Galí (1999) could be capturing the effects of permanent changes in tax rates (as opposed to those of genuine technology shocks), which could potentially account for the surprising findings.

TABLE 1. Technology and tax rates: Correlations

	BFK	VAR-P	VAR-T
TAX	-0.10	0.12	0.15
VAR-P	0.45*	1.0	0.0
VAR-T	-0.05	0.0	1.0

Notes: TAX is the first difference of the capital income tax rate constructed by McGrattan (1984) and updated subsequently. BFK is the residual from a first-order auto-regression of the ("fully corrected") measure of technological change for the private economy found in Basu, Eichenbaum, and Kimball (1999). VAR-P and VAR-T denote, respectively, the permanent and transitory shocks obtained from updated estimates of the Galí (1999) VAR, as described in the text. An asterisk indicates significance at the 5% level.

Here I try to evaluate that hypothesis by looking at simple correlations between four variables. The first variable is based on the U.S. capital income tax rate series constructed by McGrattan (1994) and recently updated by the same author.<sup>3</sup> The series is annual and covers the period 1947–1992. Since a standard ADF test cannot reject the null of a unit, and there is no evidence of a significant autocorrelation of its first-differences, I use the latter transformation as a proxy for the tax shock.

The second variable I use is based on the measure of technological change in the U.S. nonfarm private business sector constructed by Basu, Fernald, and Kimball (1999), using a growth accounting approach that allows for increasing returns, imperfect competition, variable factor utilization and sectoral compositional effects. The series has an annual frequency and covers the period 1950–1989.

The third and fourth variables correspond to the sequences of permanent and transitory shocks estimated with structural VAR similar to that in Galí (1999), and using the long run identifying restriction discussed previously. The VAR includes the first differences of (log) labor productivity and (log) hours (the latter normalized by working age population). Both variables have a quarterly frequency, refer to the nonfarm business sector and cover the period 1948:1–2002:4. Since the VAR is estimated using quarterly data, and the other two variables have an annual frequency, I annualize the series by averaging the shocks corresponding to each natural year.

Table 1 reports the contemporaneous correlations among the four variables described before, estimated in each case using the longest sample period for which they overlap.

The results convey an unambiguous message. First, innovations to the capital income tax rate show a near zero correlation with the permanent shocks from the VAR. Thus, there is no support for the hypothesis that the permanent shocks to labor productivity identified in Galí (1999) as technology shocks could be effectively capturing changes in capital income taxes. Secondly, and

3. The reader is referred to McGrattan (1994) for details on how the series was constructed.

most interestingly, the correlation between the VAR-based permanent shocks and the measures of technological change constructed by Basu, Fernald, and Kimball (1999) (using an unrelated methodology) is positive and significant at the 5% level.

This lends support to the hypothesis that the shocks identified in Galí (1999) as technology shocks were indeed capturing shifts in the aggregate production possibilities frontier. Finally, the evidence also permits one to assess the (logically possible) conjecture that an important component of variations in technology could be transitory, in which case it could be partly reflected in the VAR-based transitory shocks, which would have then been mislabeled as “nontechnology” shocks. But the results in Table 1 do not provide any evidence for that conjecture: The VAR-based transitory shock is negatively correlated with the BFK innovation.

In conclusion, the results from the empirical analysis below suggest that exogenous variations in technology may be properly captured by the VAR-based permanent shocks in Galí (1999).

#### **4. The Role of Technology Shocks in the Euro Area Business Cycle**

In this section I present evidence on the role of technology shocks as a source of business cycles in the euro area, using the structural bivariate VAR framework with long-run identifying restrictions used in Galí (1999) and described previously. The VAR includes the first differences of (log) labor productivity and (log) employment for the Euro area, constructed by Fagan et al. (2001) and updated in 2003 as part of the ECB's Area-Wide Model project. Both variables have a quarterly frequency and cover the sample period 1970:1–2002:4.

The motivation behind the extension of the empirical framework of Galí (1999) to the euro area is twofold. First, such an analysis would seem to be of interest in itself, given the current efforts to understand the workings of the Euro area economy as a whole as a necessary step in the design of Euro-wide policies, and in particular, monetary policy. That sort of analysis is now possible thanks to the availability of historical quarterly time series for most macroeconomic variables of interest, constructed by Fagan, Hanry, and Mestre (2001) through a process of aggregation of the corresponding national series for the twelve member countries.

Second, labor input measures for the euro area display a very strong nonstationary behavior, with no sign of any trend-reverting pattern, at least for the post-1970 sample period considered here. That feature, which is reflected strongly in the outcome of unit root and stationarity tests, lies at the heart of the

literature on hysteresis in European labor markets.<sup>4</sup> Next we summarize the outcome of ADF and KPSS tests applied to (log) labor productivity and (log) employment in the euro area. The picture that emerges is clear. An ADF test (with trend and 4 lags) does not reject the null of a unit root in either case, with a  $t$ -statistic of  $-2.62$  for productivity and  $-2.55$  for employment (rejection at the 10-percent level for values lower than  $-3.14$ ). In addition the KPSS test rejects the null of stationarity in both of them: the test statistic ( $\eta_r$ , allowing for trend and 4 lags) takes a value of  $0.49$  in the case of productivity and  $0.33$  for employment (rejection at the 1% level for values above  $0.216$ ). The unit root in productivity is a necessary condition for the identification strategy proposed in Galí (1999) to be meaningful. The unit root in employment warrants the introduction of that variable in first-differences in the VAR.

The above unit root characterization of employment in the euro area seems to contrast with the corresponding evidence for U.S. labor input measures, for which the outcome of such tests is often ambiguous. As Christiano, Eichenbaum, and Kimball (2003) have argued, some of the VAR-based findings regarding the effects of technology shocks in the United States appear to be sensitive to the transformation of labor input used. In particular, those authors argue that first-differencing of (log) hours may distort the sign of the estimated response of that variable to a technology shock, if hours are truly stationary.<sup>5</sup> From that viewpoint, the use of an alternative data set for which there is less controversy regarding the appropriate transformation of labor input would seem to be desirable.

Figure 1 displays the estimated effects of a (positive) technology shock. The graphs on the left show the dynamic responses of (log) labor productivity, (log) GDP, and (log) employment, together with two standard error bands.<sup>6</sup> The corresponding graphs on the right show the distribution of each variable's response on impact.<sup>7</sup> The estimates suggest a decline in employment on impact and, as a result, a "dampened" response of GDP in the face of a positive technology shock. Notice that the distribution of the estimate of the impact effect on employment assigns a low probability to an increase in that variable. The main difference with the evidence for the United States as reported in Galí (1999) lies in the apparent permanent effect of a technology shock on employment in the Euro area, in contrast with the relatively quick recovery (and even sign switch) in the United States. On the other hand, and perhaps not surpris-

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4. See, e.g., Blanchard and Summers (1986).

5. See also the discussion in Francis and Ramey (2003).

6. The response of (log) GDP is obtained by adding those of (log) employment and (log) productivity.

7. That distribution is obtained by means of a Monte Carlo simulation based on 500 drawings from the distribution of the reduced-form VAR distribution.

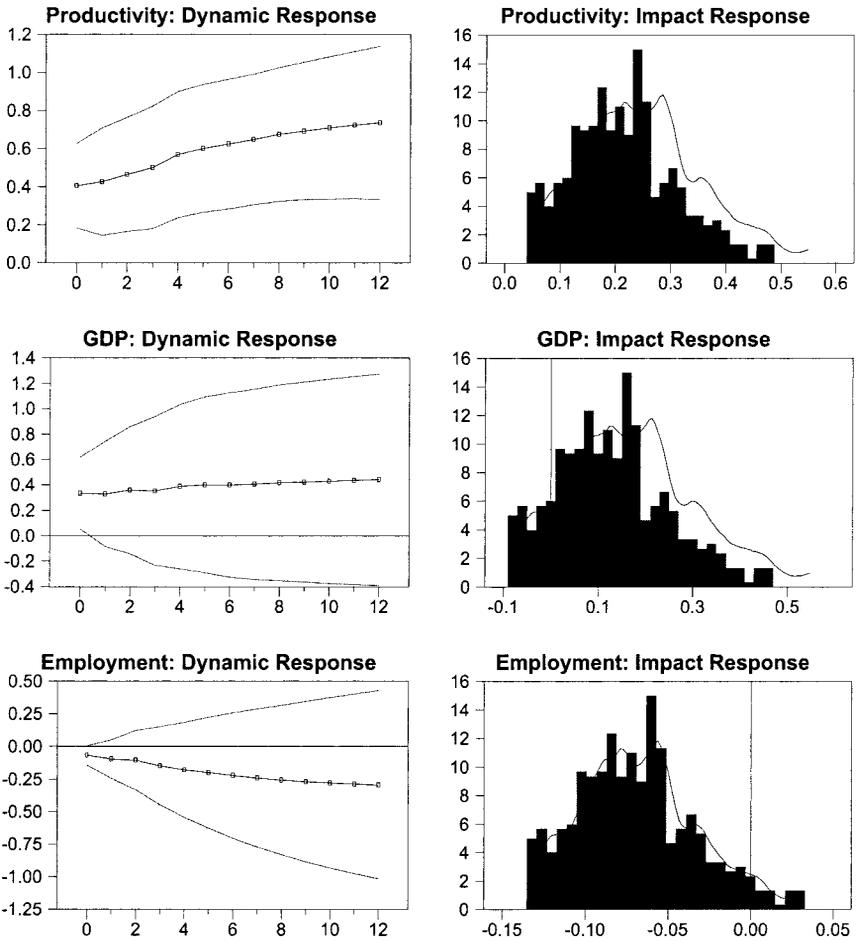


FIGURE 1. The effects of technology shocks in the Euro area. Sample period for employment and first differences was January 1970–April 2002.

ingly, the evidence in Figure 1 is qualitatively similar to that reported in Galí (1999) for Germany, Italy, and France, individually.

Figure 2 displays the estimated components of the historical series for GDP and employment associated with technology and nontechnology shocks. In the four cases the initial estimated components have been detrended using a band-pass filter that removes fluctuations of periodicity outside the interval between 6 and 32 quarters. As in the U.S. case (see Galí 1999) the picture that emerges is very clear: fluctuations in employment and GDP driven by technology shocks account for a small fraction of the variance of those variables (5% of employment and 9% of GDP). Furthermore, the comovement between employment and

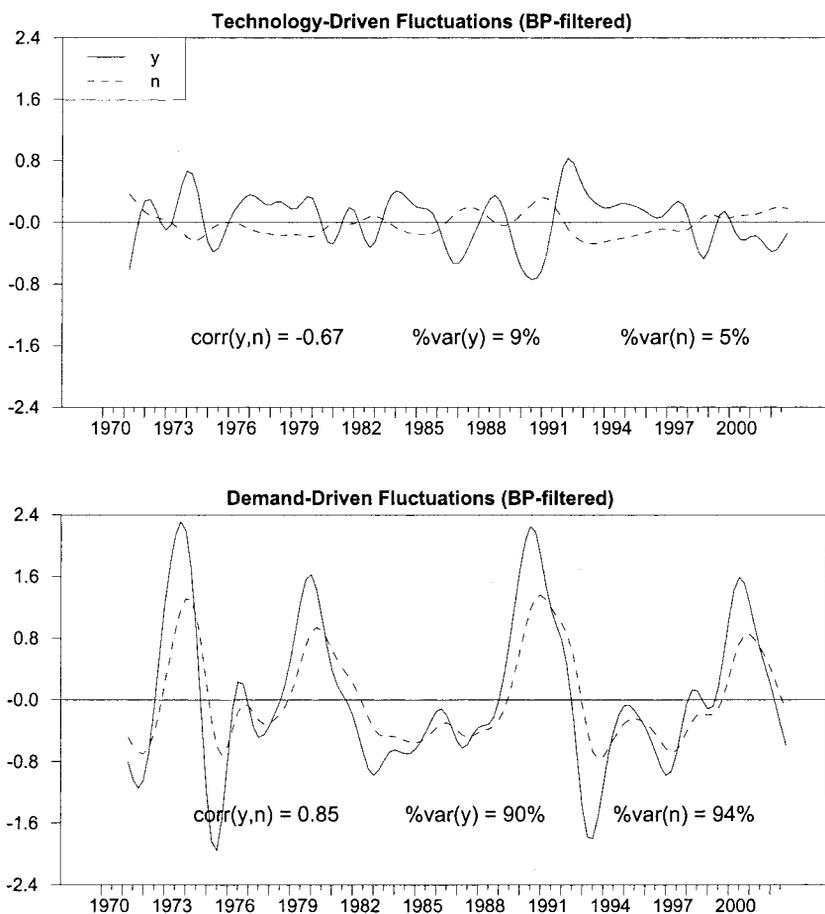


FIGURE 2. Sources of fluctuations in the Euro area. Sample period for employment and first differences was January 1970–April 2002.

GDP resulting from technology shocks is negative (the correlation is  $-0.67$ ), in contrast with the high positive comovement observed in the data ( $0.75$ ). Clearly, the pattern of technology-driven fluctuations shows little resemblance with conventional business cycle fluctuations.

Things are quite different when we turn our attention to the components of GDP and employment fluctuations driven by shocks with no permanent effects on productivity (and which are referred to as demand shocks in the graph). Those shocks account for  $94\%$  and  $90\%$  of the variance in employment and GDP, respectively. In addition, they generate a positive correlation ( $0.85$ ) between the same variables. In contrast with their technology-driven counter-

part, this component of GDP and employment fluctuations displays a more characteristic business cycle pattern.

## 5. Summary and Conclusions

I have provided some new evidence that reinforces the conclusion in Galí (1999) that exogenous variations in technology play a very limited role, if any, as sources of the business cycle. First, I have provided evidence that supports the identification of technology shocks proposed in that paper. In particular, those shocks are significantly positively correlated with independent measures of technological change, and uncorrelated with measures of capital income tax changes. Secondly, I have shown that similar findings obtain when the same approach is implemented for the euro area, using a newly available data set. Overall the findings call into question the relevance of RBC models for the understanding of economic fluctuations, both in the United States and the Euro area.

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