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Economics Letters 82 (2004) 91–97

**economics  
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# R&D expenditure in G7 countries and the implications for endogenous fluctuations and growth

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Received 13 January 2003; received in revised form 11 June 2003; accepted 28 July 2003

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## Abstract

The literature on endogenous growth cycles predicts countercyclical R&D expenditure. Aggregate R&D expenditure in G7 countries from 1973 to 2000 tends to be procyclical. Implications for future theoretical research are discussed.

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*Keywords:* Cyclical properties of R&D expenditure; Growth cycles

*JEL classification:* C2 econometric methods: single equation models: general; E32 business fluctuations, cycles; O41 one, two; multisector growth models

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## 1. Introduction

Growth rates of virtually all economic variables are time varying. The reasons for these fluctuations are manifold. Some of the factors implying nonconstant growth rates can reasonably be considered to be exogenous. Oil price shocks, shifts in preferences or sometimes also shifts in expectations can be put in this category. However, fluctuations can also be the result of events that are endogenous to an economy. As Bental and Peled (1996), Matsuyama (1999, 2001) and Wälde (1999, 2002) have stressed, intentional R&D by profit maximizing firms cannot only be the source for positive long-run growth rates but also for short-run fluctuations.

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Models presented by these authors combine capital accumulation with R&D. Generally speaking, these model economies feature a growth path on which periods of high growth are followed by periods of low growth and vice versa. Similarly, periods of high innovative activity are followed by periods of low innovative activity. Whereas in Matsuyama's work, a temporary patent protection for innovators leads to a synchronization of innovative activity, it is relative returns for investors in Bental and Peled and Wälde's approach that coordinates investment decisions.

A common prediction of these models is a countercyclical allocation of resources to R&D.<sup>2</sup> In periods of high returns to capital (or no patent protection) and high growth of GDP, few resources are allocated to R&D. With low returns to capital (or temporary patent protection) and low growth, resource allocation to R&D is high. Empirically speaking, resource allocation to R&D should be negatively correlated with growth rates of GDP. The present paper tests this prediction.

A widely used technique to do this is to detrend the data using the Hodrick–Prescott (HP) filter and calculate descriptive statistics based on the filtered series. However, it is well known that the HP filter can create spurious cyclical structure and spurious correlations (Harvey and Jaeger, 1993) if the series is  $I(0)$ . Given the limited reliability of unit-root tests (e.g. Banerjee et al., 1993) to discriminate between  $I(0)$  and  $I(1)$  series, and the shortness of our time series, we adopt the approach proposed by Canova (1998). We compare the outcome for filtering techniques with different implications for the nature of the non-stationarity, and judge the robustness of our results by comparing the outcome.

Evidence on cyclical behavior of R&D is provided by Saint-Paul (1993) and Geroski and Walters (1995). Saint-Paul uses a VAR approach and finds “very little evidence of any pro- or countercyclical behavior” of R&D activity (measured by R&D expenditure). Geroski and Walters, using UK innovations and patents data, find some procyclical behavior of these quantities (correlation coefficients of 0.62 and 0.23, respectively). Fatás (2000) provides a plot of growth rates of R&D expenditure and GDP for the USA from 1961 to 1996 and argues that they are procyclical. We complement these studies by being more comprehensive both with respect to countries and years covered, by using different data and methods and by stressing the link to theories of endogenous fluctuations and growth.

## 2. Results

### 2.1. *The data and descriptive statistics*

We study G7 countries and use annual data for the period from 1973 to 2000 (and 1973–1999 for France). This time period and frequency is largely dictated by the availability of data on R&D. Data on business enterprise R&D expenditure in current national prices are from OECD (1997, 2002a). GDP data in current national prices and price deflators used to express time series in 1995 prices are from OECD (2002b). R&D and GDP data are divided by total employment (OECD, 2002b) and the resulting per-capita (i.e. per number of workers) series are used for all computations.

Time series for Germany cover West Germany only. As data for West Germany is not available up to 2000, data for West Germany for 1991 to 2000 are constructed by multiplying data for Germany as a whole by the 1991–1994 average ratio of West German to German data. As results obtained for

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<sup>2</sup> Francois and Lloyd-Ellis (in press) obtain this result in a multisector economy without capital accumulation.

Germany do not qualitatively differ from results for other G7 countries, these added observation errors do not seem to be substantial.

The annual (unweighted) average growth rate of real per-capita GDP of G7 countries amounts to 1.5%, ranging from 0.8% for Canada to 2.1% for Japan. The annual (unweighted) average growth rate of real per-capita R&D expenditure of G7 countries lies at 3.0% with extreme values at 1.5% for the UK and 4.7% for Canada. In each country, except the UK, the growth rate of R&D expenditure lies above the growth rate of GDP. The ratio of R&D expenditure to GDP in 1997 lies between 0.5% in Italy and 2.1% in Japan. Volatility (measured by the standard deviation of the cyclical component of a time series detrended by the HP filter with a smoothing parameter  $\lambda = 100$ ) of R&D exceeds volatility of GDP by a factor between approximately 2.2 for the UK and 5.5 for Canada. Due to this much higher volatility (unweighted average 4.0), R&D expenditure can be considered to behave very similarly to “normal” investment.

## 2.2. Procyclical R&D expenditure

The trend and cyclical components of a time series are obtained by applying the various filters on logarithms of per-capita GDP and per-capita R&D data. We use the HP filter, a modified Baxter and King filter (BKM), the Christiano and Fitzgerald filter (CF) and a difference filter (DF), i.e. we computed growth rates by computing the differences of logs of time series. The smoothing parameter for the HP filter is  $\lambda = 100$  and  $\lambda = 6.25$  (suggested recently by Ravn and Uhlig, 2002), the modified Baxter and King (1999) filter has a cut-off frequency of 15 years, the filter length is 3. The undesirable sidelobes in the gain function are taken care of by the so-called Lanczos’s  $\sigma$ -factors (as used in A’Hearn and Woitek, 2001). For the Christiano and Fitzgerald (1999) filter, the cut-off frequency is again 15 years.

Correlation coefficients and corresponding  $t$ - and  $p$ -values are obtained by regressing centered cyclical components of per-capita R&D data on centered cyclical components of per-capita GDP, correcting standard errors for heteroskedasticity and autocorrelation (Newey and West, 1987). Fig. 1 gives a visual summary of results by plotting a dot corresponding to the estimated correlation coefficient for R&D leads of 2 and 1 years (starting from the left), for contemporaneous correlations and for R&D lags for 1 and 2 years. Correlation coefficients significant at the 10% level or higher are marked by the corresponding country name.<sup>3</sup>

Starting with contemporaneous correlations, six out of seven correlation coefficients are positive for the HP100, CF and difference filters, four out of seven are positive for BKM. Ten correlation coefficients are significant, of which only one is negative (Italy). This clearly shows the procyclical nature of contemporaneous R&D expenditure.

Looking at leading and lagging R&D, correlation coefficients tend to be less positive. Counting estimates, only 54 out of 112, i.e. 48% remain positive. This contrasts to 79% positive estimates for contemporaneous correlations. The numbers of significant estimates for leading and lagging R&D are also lower: while there are seven significant estimates for a lead of 2 years, there are only three for a lead and a lag of 1 year and only one for a lag of 2 years. Both the unclear result about the sign of lagged

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<sup>3</sup> Due to space constraints, results for the HP6.25 filter (which conform to the overall impression) are not presented here. All results including estimated correlation coefficients and  $t$ - and  $p$ -values are contained in a table appendix, which is available upon request.

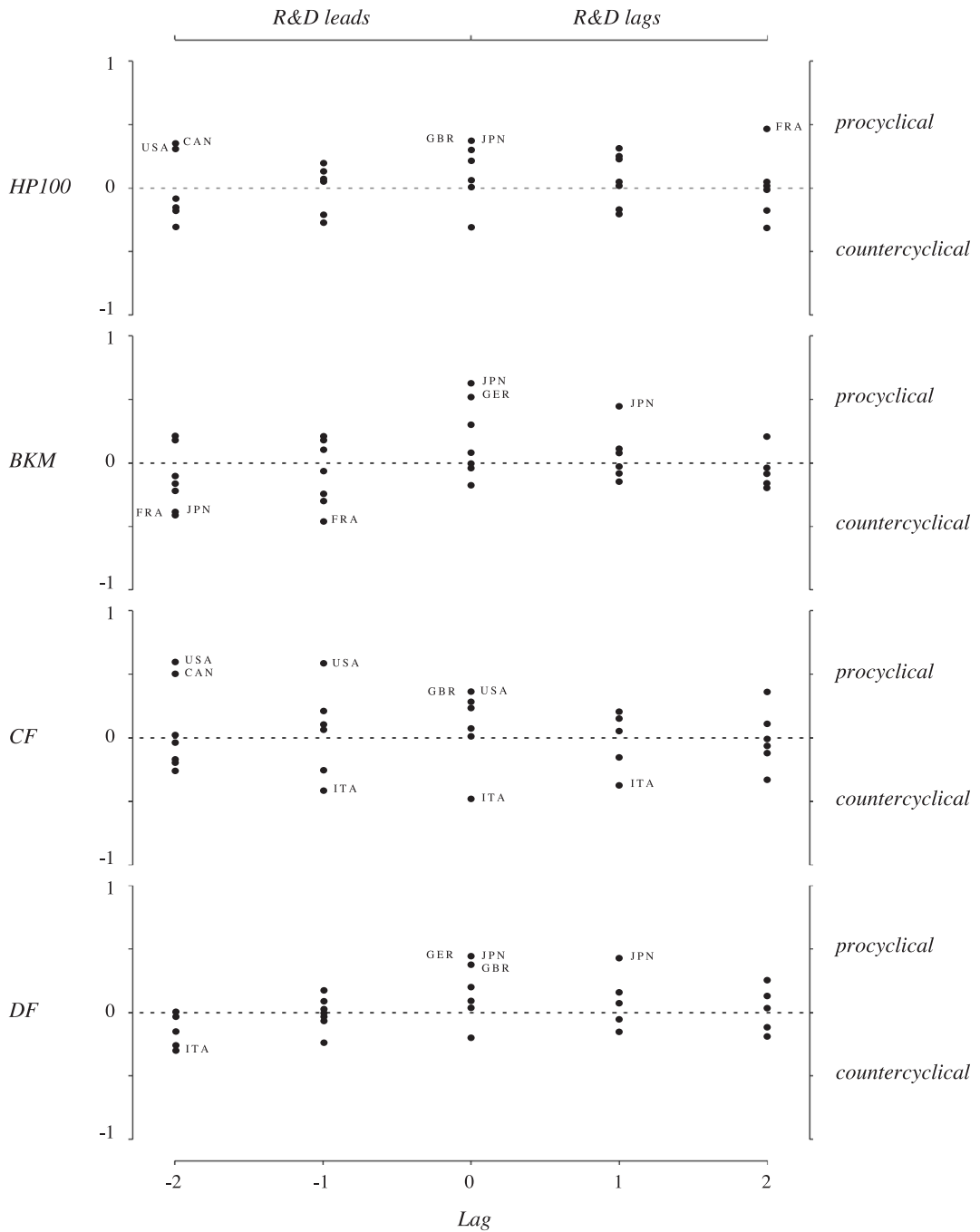


Fig. 1. Correlation coefficients between GDP and R&D expenditure for G7 countries.

correlation coefficients and fewer significant estimates show that R&D and GDP are, if anything, contemporaneously correlated. The effect that estimates tend to become less positive is a result one should expect: when two time series of the same length are contemporaneously procyclical, they need to be countercyclical if one time series is lagged by half the length of a cycle.

### 2.3. *Research vs. development and R&D vs. investment*

While the overall impression is clearly one of a positive contemporaneous correlation, some exceptions remain like the significant negative correlation coefficient for Italy under the CF filter. For other filters, Italy also always has a negative, though not significant correlation coefficient. This section therefore undertakes two further investigations to understand implications for economic theory.

First, we ask to what extent correlation coefficients for total R&D expenditure differ from correlation coefficients for ‘basic research’, ‘applied research’ and ‘development’ expenditure, the three components that add up to the total R&D expenditure. One could expect that basic research, being more long-term oriented, is not as cyclical as applied research, which might have a shorter horizon. Individual components might therefore have different cyclical properties from aggregate R&D expenditure. Unfortunately, OECD data on basic vs. applied research is available only as of 1981 (OECD, 2003) and complete time series are provided only for Italy, Japan and the USA. An analysis of correlation coefficients for Italy and Japan does not provide further information concerning implications for theory.

Time series for basic and applied research and development for the USA from 1953 to 1998 is available from NSF (2003). Correlation coefficients for this longer time period confirm findings presented in Fig. 1. Contemporaneous correlation coefficients for total R&D expenditure (financed by ‘Company and other’, i.e. excluding federal funds) are positive for all five filters and significant in three cases. There is also an interesting pattern concerning individual components. For four out of five filters, applied research is negatively correlated, though never significantly. This confirms findings by Francois and Lloyd-Ellis (in press, their Fig. 4). Basic research is negatively correlated in three cases, also never significantly. Development, however, the third component, is always positively correlated and four times in a significant way. Total R&D expenditure in the USA is therefore procyclical because of the strong procyclical behavior of ‘development’, despite weak countercyclical behavior of ‘basic’ and ‘applied’ research.

Second, we estimate the correlation between investment (gross fixed capital formation from OECD, 2001) and R&D expenditure. This follows directly from theory: the most direct prediction of existing models of endogenous fluctuations is the switching allocation of savings to either capital accumulation or R&D and hence their negative correlation. The prediction of a negative correlation between R&D expenditure and GDP tested so far is “only” an implication. Here, only 5 out of 28 (again not counting the HP6.25 results) estimated correlation coefficients are negative, and none is significant. By contrast, 12 positive correlation coefficients are significant. Correlation coefficients for Italy are positive for the HP100, BKM and CF and negative for the difference filters. The BKM coefficient is significant.

These findings on correlation between investment and R&D give an even clearer picture on the hypothesis of a negative correlation between R&D expenditure and GDP (and aggregate investment) made by theory. The theoretical prediction is clearly rejected, even for Italy.

### 3. Conclusion

What do these findings imply for further research? Bental and Peled (1996) briefly and Francois and Lloyd-Ellis (in press) extensively discuss empirical evidence on countercyclical R&D expenditure.<sup>4</sup> These authors provide evidence in favour of their—and therefore also—Matsuyama's and Wälde's approach. Generally speaking, some R&D activities (in a broad sense including reorganization of production or management processes and training) indeed seem to increase during downturns. On the other hand, it seems fair to argue that there is stronger evidence for procyclical rather than countercyclical behavior of R&D expenditure from the analysis undertaken here.

While data might remain inconclusive for some time, future research should focus on making models more flexible. Other specifications might imply R&D expenditure whose cyclical behavior depends on parameter values. This might then help to find new empirical strategies that would allow to understand why there is both pro- and countercyclical evidence of R&D in a broad sense.

### Acknowledgements

We are grateful to Gunter Coenen, Antonio Fatas, Gerhard Glomm, Alfred Mausner, Bernd Süßmuth, Mark Weder and an anonymous referee for many constructive comments.

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<sup>4</sup> Cf. also Saint-Paul (1993, 1997) on the related “opportunity cost” literature.

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