ISSN 0265-8003

STYLIZED FACTS OF BUSINESS CYCLES IN THE G7 FROM A REAL BUSINESS CYCLES PERSPECTIVE

Riccardo Fiorito and Tryphon Kollintzas

Discussion Paper No. 681
July 1992

Centre for Economic Policy Research
25-28 Old Burlington Street
London W1X 1LB
Tel: (44 71) 734 9110

CEPR Discussion Paper No. 681

July 1992

ABSTRACT

Stylized Facts of Business Cycles in the G7 from a Real Business Cycles Perspective*

This paper investigates the basic stylized facts of business cycles in the G7 countries using quarterly data from 1960-89. The methodology used is based on Kydland and Prescott (1990). The evidence suggests that the real business cycles model can account for several important stylized facts for all seven countries. In particular, consumption is procyclical and fluctuates generally less than output; investment is procyclical and fluctuates more than output; net exports are countercyclical; prices are countercyclical; and money does not have a clear-cut cyclical pattern. Real business cycles models cannot at present account for some basic stylized facts of labour dynamics, however, primarily because they cannot account for variations in total hours and hours per worker. This and other evidence suggests that labour hoarding might, especially in Europe and Japan, be the main force behind employment dynamics.

JEL classification: E30, E31, E32
Keywords: business cycles, real business cycles model, labour hoarding, adjustment costs, variable employment utilization

Riccardo Fiorito
Department of Economics
University of Siena
Piazza S Francesco
53100 Siena
ITALY
Tel: (39 577) 298 610

Tryphon Kollintzas
Department of Economics
Athens University of Economics and Business
76 Pattision Street
104-34 Athens
GREECE
Tel: (30 1) 821 1938

*We have benefited from several discussions with Finn Kydland and from comments by seminar participants at the University of Wisconsin, the University of Pittsburgh, the London School of Economics and the Athens University of Economics and Business. The usual proviso applies.

Submitted 6 May 1992

NON-TECHNICAL SUMMARY

In recent years, the stylized facts of business cycles have again been at the forefront of research in macroeconomics. This renewed interest is mainly due to the work of Kydland and Prescott, who have attempted to explain the basic features of business cycles in the US economy using stochastic dynamic general equilibrium models based on the so-called 'real business cycle' (RBC) model. This model suggests that business cycles are the result of exogenous technology shocks, which are propagated by the optimizing behaviour of economic agents operating in competitive environments. The derivation and interpretation of the Kydland and Prescott results have been controversial issues, but there have been few attempts to confront the RBC model with alternative data sets. We attempt to do so in this paper, which investigates the stylized facts of business cycles in the G7 countries using quarterly data from 1960-89. The analysis has two objectives. The first is to ascertain whether the stylized facts of these economies can or cannot be accounted for by current versions of the RBC model. The second objective is to provide some critical explanations whenever current versions of the RBC model fail to account for these facts and suggest some directions for possible modifications. The methodology used is based on Kydland and Prescott.

The evidence suggests that current versions of the RBC model can qualitatively (and often quantitatively) account for several important stylized facts in all seven economies. Confirming Backus and Kehoe, we find considerable regularities among countries in the behaviour of output and its expenditure components, except government spending. In particular, these components are procyclical, consumption fluctuating generally less and investment considerably more than real GNP or GDP. Confirming Kydland and Prescott's finding for the United States, we find prices are countercyclical in all countries. The last result also confirms Backus and Kehoe's finding about the countercyclical behaviour of prices in the post-war period in several countries. Further, money does not have a clear-cut pattern and its behaviour varies both across countries and definitions of money stock.

The major discrepancies between the RBC model and the evidence for the G7 countries are in labour dynamics. First, variations in employment seem to be too small and variations in hours per worker seem to be too large to be accounted for by existing versions of the RBC model. Second, employment lags output everywhere while hours per worker are coincidental or leading, contrary to RBC formulations where employment adjustments are explicitly or implicitly synchronous to output.

Although the variability of total hours predicted by some versions of the RBC model is about right, the variability of the components of total hours is not. In some of these models hours per worker are fixed, so that all the variability is due to variability in employment. Moreover, models that allow for hours-per-worker variability seem to grossly underpredict this variation and fail to recognize the lagging employment adjustment.

A modification of the RBC model that could, in principle, account for these findings implies some type of labour hoarding; that is, a situation where firms find it relatively more costly to adjust employment rather than hours per worker, so that they have an incentive to smooth employment over the business cycle and utilize labour more intensively in expansions and less intensively in contractions. This is consistent with survey and time-series data in US manufacturing and elsewhere. Further, it is consistent with the facts that employment in the European countries and Japan fluctuates relatively less than in the North American countries and total hours fluctuate considerably more than employment. It is generally believed that labour institutions in Europe and Japan create more potent adjustment costs and flow of information impedients. Thus, labour hoarding type behaviour may be more important in the European countries and Japan.

We conjecture that it is possible in principle to construct RBC models that can account for the variation in hours per worker and employment and the tendency of employment to lag behind output. These models should incorporate adjustment costs and variable employment utilization. Adjustment costs may reflect technological or institutional factors guiding search by heterogeneous workers and union behaviour.

1. INTRODUCTION

In recent years, the stylized facts of business cycles have been again in the forefront of research in macroeconomics.[1] This renewed interest is mainly due to the work of Kydland and Prescott (1982, 1988, 1990, 1991), who have engaged in an attempt to explain the basic features of business cycles in the US economy with stochastic dynamic general equilibrium models capable of generating artificial data.[2] These models are variations of the so called "real business cycles" (RBC) model, which descends from the work of Solow (1956), Cass (1965), Koopmans (1965), and Brock and Mirman (1972). It is well known that the thesis of this model is that business cycles are the product of exogenous technology shocks and the (shock) propagation mechanism generated by the optimizing behavior of economic agents operating in competitive environments.[3] The derivation and interpretation of the Kydland and Prescott results have been controversial issues (See, e.g., the exchange between Prescott(1986) and Summers (1986) and the critical paper of Eichenbaum (1991)). In the meantime, there has been a number of papers that modify and/or extend the RBC model, so as to focus on a particular subset of business cycle behavior or to address simulation problems or statistical inference. Very little has been done, however, to confront the RBC model with alternative data sets.[4] In this paper we wish to pursue that tack.

In particular, the purpose of this paper is to investigate the basic stylized facts of business cycles in the G7 countries using quarterly data from 1960 to 1989 and the RBC model as guidance. The main objectives of the analysis are two. The first is to ascertain whether the stylized facts of these economies can be accounted for by current versions of the RBC model. The second objective is to provide some critical explanations whenever the RBC model fails to account for these facts and suggest some directions for possible modifications or alternative explanations. We do not aim, however, at comparing different business cycle theories in terms of their relative fit vis a vis a common set of stylized facts. For comparison purposes, the methodology used is mainly that of Kydland and Prescott (1990).

The paper has four sections. Section 2 presents the methodology. Section 3 presents and discusses the selected stylized facts. Section 4 offers some conclusions.

It should be mentioned at the outset, that current versions of the RBC model can qualitatively and often quantitatively account for several important stylized facts of all seven economies. Confirming Backus and Kehoe (1989), we find considerable regularities among countries in the behavior of output and its expenditure components, except government spending. In particular, these components are procyclical, consumption fluctuates generally less and investment considerably more than real GNP/GDP. Confirming Kydland and Prescott's (1990) finding for the United States, we find prices are countercyclical in all countries. The last result also confirms Backus and Kehoe's (1989) finding about the countercyclicality of prices in the post WWII period in several countries. Further, money does not have a clear cut pattern and its behavior varies both across countries and definitions of money stock.

But, current versions of the RBC model do not seem to be able to account for some basic stylized facts of labor dynamics. This is primarily because these models cannot account for the variations in total hours and hours per worker. Then, since employment lags output both at the overall, industry, and manufacturing levels and, moreover, has a considerably smaller variability than output, especially in Europe and Japan, it seems that labor hoarding rather than technology shocks may be the main force behind labor dynamics.

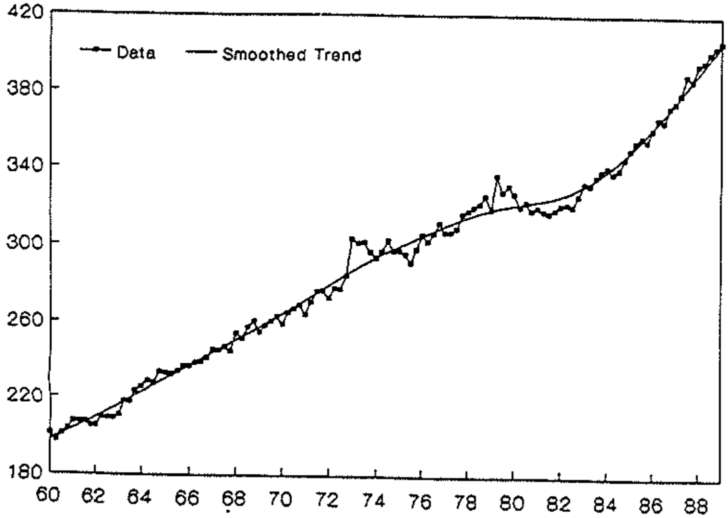
2. METHODOLOGY

The cornerstone of the theory and measurement of the RBC model is, actually, its assumption about economic growth: namely, that steady state growth emanates from exogenous labor-augmenting technical change and that this rate varies over time and (especially important for this study) across countries. Then, one can define the growth and business cycles components of a variable as its smoothed trend and the deviations of the smoothed trend from the actual values of the variable, respectively (Lucas (1977)).[5]

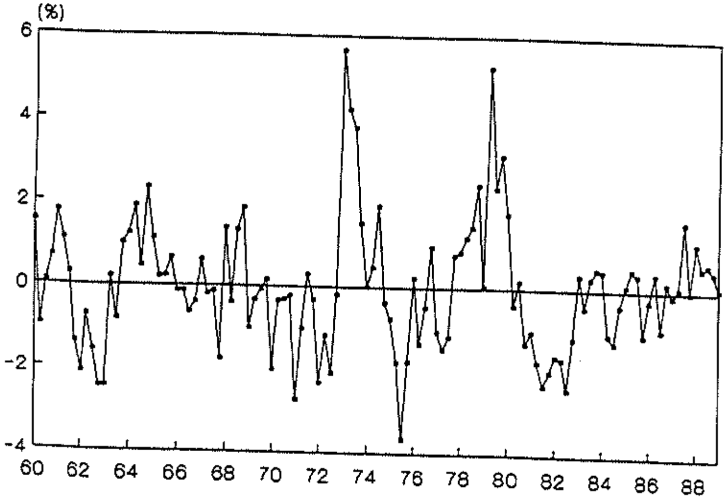
There are, of course, many methods to construct smooth trend.[6] For comparison purposes, in this paper we have chosen to do so by employing the method developed by Hodrick and Prescott (1980) (henceforth, HP). We present the HP filter and its interpretations in Appendix A. Briefly, however, the HP filter has been designed so as to satisfy the following criteria (Kydland and Prescott (1990 p. 8)):

> The trend component of real GNP should be approximately the curve that students of business cycles and growth should draw through a time plot of this time series.
> The trend of a given time series should be a linear transformation of that time series, and that transformation should be the same for all series. Lengthening the sample

GDP OF U.K.



GDP OF U.K.
PERCENTAGE DEVIATIONS FROM TREND



> period should not significantly alter the value of the deviations at a given date, except possibly near the end of the original sample. The scheme should be well defined, judgement free, and cheaply reproducible."

An illustration of this filter using the quarterly real GDP data of the United Kingdom, is depicted in Figure 1.

However, there are some potential problems with the way the HP filter is used to study business cycle fluctuations. Most importantly, there are two consistency issues in ascertaining whether the stylized facts of business cycle fluctuations that have been obtained from the HP filter can be accounted for by the RBC model. First, we are not going to examine whether the growth and the business cycles components of the variables involved interact in a way that is consistent with this model.[7,8] Second, using the HP filter to derive the business cycle component of any given variable separately does not ensure that the pertinent variables have a common growth component, as required by the theory. A cursory check of a few of these variables, for which we performed cointegration tests in Appendix D shows that this may be a real problem. For several countries, but especially for Italy and France, the growth components of several variables fail to be cointegrated at the usual levels of significance.[9]

Finally, it has been reported (King and Rebelo (1990), Cogley (1990), and Harvey and Jaeger (1991)) that the HP filter may seriously alter measures of persistence, relative variability, and comovements. This seems to be somewhat of a problem for comparing measures of relative variability, persistence, and comovements between actual and artificially created data. Nevertheless, we checked whether measures of comovement between output and price, output and money, and output and employment remain robust under unit root and log-polynomial deterministic trends. The results of our sensitivity analysis are reported in Appendix C. It is important to mention that, in general, we do not find that the essential results of our study would be altered.

On several occasions we encountered series that they were not seasonally adjusted (s.a.). To remove seasonality we followed a dummy variables procedure in which the growth component is consistently obtained by applying to the data the HP filter rather than the usual log-polynomial trend. We explain our procedure in Appendix B.

Again, for comparison purposes, the statistics we present are those of Kydland and Prescott (1990). For each series we report the following: (a) the percentage standard deviation of the series (as a measure of the relative amplitude of the fluctuations in the series); (b) the cross correlation of the series with real GNP/GDP or an industrial output variable (as an indicator of the type of comovement of the series with GNP/GDP or the appropriate industry output variable).

Thus, for a given variable X and the pertinent GNP/GDP or industry output variable, Y, the comovements we examine are classified as follows. If $\rho(j)$, $j \in \{0, \pm1, \pm2, ...\}$, denotes the cross correlation between Y_t and $X_{t \pm j}$, we say that, the cycle of X is leading, is synchronous, or is lagging the cycle of Y as $|\rho(j)|$ is maximum for a negative, zero, or positive j, respectively. And, we say that X is procyclical (countercyclical) as $\rho(0)$ is positive (negative) and not very close to zero. In particular, for $.5 \leq$

$|\rho(0)| < 1$ we use the adverb "strongly", for $.2 \leq |\rho(0)| < .5$ we use the adverb "weakly" and, when $0 \leq |\rho(0)| < .2$ we say that the series are contemporaneously uncorrelated. [10] Also, the corresponding elasticities of the real GNP/GDP with respect a given variable at a certain lag/lead can be recovered by multiplying the relevant correlation coefficients by the relative variability (σ_y/σ_x). Finally, for GNP/GDP shares we also present the mean of the series (Table 1B).

3. STYLIZED FACTS

As already noted we let the RBC model dictate which facts to examine and how to organize them. Thus, the stylized facts presented below are grouped in three categories: (a) the components of spending, income, and output; (b) prices and monetary variables; and (c) the factors of production. This order is different from KP, for we left what we think are the most controversial, from an RBC perspective, stylized facts to the end.

Our data are OECD's Main Economic Indicators (MEI) as released in a RATS format by VAR Econometrics. The sample has not been divided in sub-periods because the smoothed trend itself should be able to capture the most important structural breaks. For reference purposes, we shall refer to the RBC model presented in Prescott (1986) as the Benchmark Real Business Cycles (BRBC) model. This model features a logarithmic additively separable temporal utility function in consumption and leisure; a Cobb-Douglas production function in capital and labor inputs; an AR(1) technology shock with innovations that are observed at the time the contemporaneous decisions about consumption, leisure, capital and labor inputs are made; and fixed geometric depreciation of capital stock. Although, the BRBC model does not perform quantitatively as well as some of its more elaborate counterparts, it is most suitable for a benchmark as most other versions of the RBC model may be thought of as its extensions.

3.1 <u>The components of spending.</u>

Data on GNP/GDP and the components of spending are presented in Tables 1A and 1B. The nature of GNP/GDP fluctuations will be examined in detail in Subsection 3.3. For reference purposes however, it is important to briefly discuss them first.

In all seven countries GNP/GDP deviations from smooth trend have about the same volatility and are strongly positively autocorrelated, showing strong persistence in the business cycle fluctuations, with the exception of the United Kingdom. These findings are both consistent with the findings of KP and those of Backus and Kehoe (1989) (henceforth BK), who used annual century long data for a set of ten countries including Canada, Germany, Italy, the United Kingdom, and the United States.

Qualitatively, in the BRBC model persistence in GNP/GDP is explained even without persistence in the technology shock. Intuitively, the income effect of a "good" temporary technology shock creates an incentive to consume more and work less in the current period as well as in future periods and the substitution effect of this happening creates an incentive to consume more in the current and future periods and to work more in the current

TABLE 1A: THE COMPONENTS OF SPENDING, INCOME, AND OUTPUT IN LEVELS [1]

Variable	Vol.	X_{t-5}	X_{t-4}	X_{t-3}	X_{t-2}	X_{t-1}	X_{t}	X_{t+1}	X_{t+2}	X_{t+3}	X_{t+4}	X_{t+5}
(1) Real GNP/GDP												
USA	1.74	.01	.21	.41	.65	.85	1.0	.85	.65	.41	.21	.01
Canada	1.39	-.12	.04	.27	.51	.78	1.0	.78	.51	.27	.04	-.12
Japan	1.53	.02	.19	.38	.59	.78	1.0	.78	.59	.38	.19	.02
Germany	1.69	-.02	.23	.35	.46	.67	1.0	.67	.46	.35	.23	-.02
France	.90	-.06	.10	.30	.54	.77	1.0	.77	.54	.30	.10	-.06
UK	1.54	-.02	.07	.20	.37	.55	1.0	.55	.37	.20	.07	-.02
Italy	1.70	-.21	-.04	.22	.52	.80	1.0	.80	.52	.22	-.04	-.21
(2) Consumption Expenditure												
US	1.29	.32	.48	.59	.72	.79	.80	.63	.43	.22	.00	-.17
Canada	1.27	-.08	.16	.40	.57	.72	.79	.65	.44	.27	.06	-.03
Japan	1.33	-.10	.08	.28	.42	.56	.72	.54	.40	.22	.01	-.11
Germany	1.53	.11	.26	.37	.46	.58	.69	.55	.49	.38	.32	.21
France	.86	-.27	.42	-.63	.73	.72	.62	.30	.10	-.14	.25	-.32
UK	1.67	.03	.13	.30	.39	.46	.67	.42	.38	.26	.10	.08
Italy	1.19	-.15	.07	.34	.59	.74	.78	.69	.50	.25	.03	-.15
(3) Fixed Investment												
US	5.57	.14	.30	.47	.67	.83	.90	.78	.59	.35	.12	-.09
Canada	4.60	-.43	-.29	-.07	.18	.40	.53	.52	.41	.32	.21	.14
Japan	4.57	-.11	.04	.23	.45	.64	.83	.78	.69	.51	.29	.05
Germany	4.90	.04	.26	.37	.42	.60	.84	.54	.42	.37	.29	.12
France	2.70	-.11	.06	.26	.46	.66	.78	.69	.57	.41	.25	.13
UK	3.57	-.11	-.04	.08	.23	.33	.60	.53	.38	.31	.23	.05
Italy	4.88	-.16	-.00	.23	.47	.70	.88	.81	.67	.47	.25	.05
(5) Equipment Investment												
US	6.28	-.13	.02	.21	.46	.68	.86	.87	.77	.59	.38	.18
Canada	7.13	-.49	-.35	-.18	.03	.27	.43	.51	.53	.50	.34	.25
Japan	5.96	-.09	.02	.17	.38	.58	.74	.73	.69	.54	.34	.25
Germany	6.09	.12	.36	.48	.52	.61	.73	.58	.49	.39	.34	.14
France	3.90	.08	-.23	.39	.58	.70	.74	.53	.31	.12	.23	.09
UK	4.88	-.12	-.07	.05	.21	.38	.56	.51	.47	.44	-.06	-.17
Italy	7.92	-.15	.01	.25	.48	.69	.85	.74	.57	.38	.14	-.05

TABLE 1A CONT.

Variable	Vol.	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(6) Construction Investment												
US	6.26	.31	.45	.57	.70	.80	.78	.58	.35	.11	-.10	-.27
Canada	3.83	-.23	-.12	.10	.34	.50	.55	.41	.18	.06	.01	-.04
Japan	5.58	-.04	.09	.23	.31	.32	.43	.35	.18	.07	-.05	-.18
Germany	5.56	.00	.15	.22	.27	.47	.72	.40	.28	.27	.25	.10
France	2.49	-.25	-.11	.08	.25	.48	.65	.65	.65	.54	.45	.33
UK	3.90	.15	.19	.28	.26	.21	.38	.27	.08	-.00	-.08	-.24
Italy	3.57	-.11	.00	.18	.36	.57	.74	.74	.65	.50	.36	.20
(7) Inventory Changes												
US	18.2	-.01	.08	.22	.35	.49	.64	.48	.26	.03	-.14	-.30
Canada	35.4	.07	.15	.25	.43	.60	.68	.53	.33	.06	-.18	-.32
Japan	45.4	-.05	-.03	.07	.23	.38	.38	.38	.25	.20	.20	.10
Germany	49.2	.07	.19	.31	.32	.33	.35	.29	.14	.02	-.13	-.27
France	30.1	-.15	-.09	-.04	.05	.22	.47	.44	.25	.16	-.05	-.27
UK	26.6	.03	.12	.16	.26	.42	.55	.38	.19	.00	-.08	-.17
Italy	66.8	-.07	.10	.21	.39	.51	.56	.32	.00	-.24	-.41	-.48
(8) Government final consumption												
US	1.98	-.07	-.04	.00	.06	.11	.19	.24	.27	.30	.35	.37
Canada	1.46	-.18	-.20	-.24	-.23	-.20	-.12	-.09	-.08	.05	.14	.18
Japan	2.89	.25	.33	.30	.28	.30	.32	.04	-.05	-.08	-.05	-.06
Germany	1.47	-.19	-.11	-.13	-.10	-.06	.05	.06	.16	.23	.36	.41
France	0.70	.46	.61	.56	.46	.32	.18	-.07	-.23	-.31	-.30	-.24
UK	1.43	-.09	-.03	-.07	-.06	.02	.04	-.05	-.01	-.07	-.05	.04
Italy	0.60	.30	.18	.05	-.14	-.30	-.39	-.43	-.41	-.33	-.21	-.04
(9) Exports												
US	5.22	-.48	-.41	-.29	-.13	.10	.33	.46	.49	.46	.44	.35
Canada	4.07	.05	.14	.27	.37	.52	.61	.45	.30	.13	-.08	-.23
Japan	4.65	-.08	-.12	-.16	-.15	-.13	-.05	.01	.13	.21	.27	.25
Germany	3.10	-.25	-.19	-.18	-.11	.08	.38	.24	.15	.14	.04	-.05
France	2.72	-.15	-.03	.08	.26	.44	.60	.53	.39	.35	.23	.15
UK	3.20	-.09	-.18	-.12	.03	.18	.47	.20	.25	.15	.15	.10
Italy	3.61	.14	.07	.09	.11	.21	.26	.12	-.04	-.26	-.38	.34
(10) Imports												
US	5.20	.13	.21	.33	.46	.63	.75	.73	.52	.28	.06	-.16
Canada	5.15	-.24	-.06	.17	.43	.68	.79	.70	.55	.31	.04	-.11
Japan	5.60	-.25	-.13	.02	.24	.39	.47	.48	.46	.39	.28	.14
Germany	3.53	.05	.19	.36	.46	.60	.70	.61	.55	.47	.25	.12
France	4.11	-.06	.13	.31	.50	.71	.82	.67	.41	.18	-.06	-.22
UK	3.93	-.09	.02	.15	.30	.50	.53	.51	.45	.26	.15	.03
Italy	5.75	-.04	.13	.33	.50	.65	.70	.58	.33	.05	-.15	-.20

[1] Default ranges for samples are: US, Canada, Japan, and Italy (60Q1-89Q3
Germany (60Q1-89Q2), France (70Q1-89Q3), and UK (60Q1-89Q1).

TABLE 1B: THE COMPONENTS OF SPENDING, INCOME, AND OUTPUT IN SHARES[2]

Variable	Mean	Vol	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(1) Consumption Expenditure													
US	.62	.66	.37	.24	.05	-.19	-.43	-.67	-.63	-.54	-.41	-.34	-.23
Canada	.55	.48	.09	.17	.15	.02	-.21	-.45	-.31	-.18	-.04	.02	.16
Japan	.59	.67	-.13	-.17	-.02	-.31	-.42	-.53	-.44	-.33	-.26	-.25	-.14
Germany	.54	.69	.17	.01	-.01	-.06	-.20	-.49	-.24	-.03	-.02	.08	.27
France	.59	.45	.37	-.34	.34	.19	-.10	-.48	-.56	-.52	-.51	-.40	-.2
UK	.60	.78	.06	.09	.15	.06	-.05	-.32	-.10	.04	.09	.04	.11
Italy	.63	.63	.47	.33	.12	-.17	-.50	-.74	-.55	-.25	.08	.34	.48
(2) Fixed Investment													
US	.16	.65	.18	.32	.47	.64	.78	.81	.71	.53	.32	.08	-.13
Canada	.18	.75	-.48	-.38	-.20	.02	.19	.26	.32	.29	.27	.23	.20
Japan	.23	.56	-.13	-.11	-.01	.22	.38	.41	.42	.28	.21	.17	.10
Germany	.23	.86	.07	.25	.33	.36	.50	.67	.41	.35	.34	.28	.17
France	.23	.48	-.13	.03	.21	.38	.54	.61	.58	.53	.41	.29	.20
UK	.18	.49	-.13	-.09	-.01	.07	.10	.20	.35	.26	.26	.24	.06
Italy	.24	.62	-.26	-.12	.08	.31	.57	.73	.78	.69	.51	.24	-.02
(3) Changes in Inventory													
US	.007	.64	.00	.08	.21	.35	.48	.65	.46	.24	.00	-.16	-.31
Canada	.009	1.01	.00	.04	.16	.33	.52	.67	.53	.36	.11	-.09	-.22
Japan	.011	.83	-.13	-.11	-.01	.22	.38	.41	.42	.28	.21	.17	.10
Germany	.008	.95	.12	.21	.33	.39	.39	.38	.32	.14	.02	-.19	-.36
France	.009	.70	-.23	-.16	-.11	.02	.25	.52	.48	.29	.19	-.01	-.23
UK	.006	.88	.01	.12	.16	.28	.45	.58	.41	.20	.02	-.07	-.17
Italy	.010	.93	-.18	.02	.19	.41	.62	.72	.53	.22	-.09	-.34	-.46
(4) Government final consumption													
US	.22	.52	-.07	-.18	-.28	-.39	-.49	-.54	-.38	-.22	-.03	.15	.3
Canada	.23	.50	-.04	-.15	-.34	-.48	-.64	-.73	-.57	-.39	-.14	.08	.21
Japan	.19	.54	.25	.24	.10	-.03	-.11	-.21	-.38	-.36	-.28	-.14	-.05
Germany	.20	.43	-.11	-.25	-.36	-.42	-.57	-.74	-.48	-.25	-.12	.07	.29
France	.19	.19	.36	.31	.11	-.16	-.46	-.75	-.71	-.62	-.47	-.29	-.11
UK	.22	.45	-.05	-.08	-.20	-.32	-.40	-.72	-.45	-.29	-.20	-.08	.04
Italy	.16	.31	.40	.17	-.13	-.48	-.79	-.97	-.83	-.55	-.21	.10	.33

TABLE 1B CONT.

Variable	Mean	Vol	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(5) Exports													
US	.09	.49	-.51	-.50	-.44	-.35	-.18	.00	.19	.29	.34	.38	.37
Canada	.25	.85	.13	.18	.24	.28	.34	.36	.24	.17	.05	-.12	-.26
Japan	.13	.54	-.09	-.13	-.20	-.23	-.26	-.24	-.16	-.04	.06	.16	.19
Germany	.25	.77	-.27	-.35	-.39	-.36	-.27	-.12	-.08	-.07	-.02	-.05	-.02
France	.20	.48	-.14	-.10	-.08	-.05	.00	.08	.06	.04	.03	.01	.00
UK	.24	.66	-.08	-.21	-.22	-.15	-.08	-.00	-.05	.09	.08	.14	.12
Italy	.19	.69	.24	.14	.07	-.04	-.10	-.14	-.18	-.21	-.30	-.29	-.19
(6) Imports													
US	.10	.40	.20	.22	.28	.34	.48	.55	.58	.40	.20	-.01	-.2
Canada	.22	.91	-.27	-.10	.12	.38	.59	.66	.63	.53	.30	.04	-.11
Japan	.15	.68	-.28	-.22	-.13	.04	.15	.20	.30	.36	-.36	.30	.20
Germany	.24	.59	.08	.09	.23	.30	.37	.31	.39	.44	.39	.19	.18
France	.22	.72	-.07	.11	.28	.46	.65	.73	.61	.36	.16	-.08	-.24
UK	.24	.82	-.10	-.03	.06	.16	.31	.16	.34	.36	.23	.16	.06
Italy	.22	.90	.24	.39	.47	.49	.53	.50	.40	.15	-.15	-.37	-.41

[2] Shares have not been logged.

period and less in the future periods. Either effect implies that savings and investment must rise so as create the additional capital necessary to produce more output and enjoy more consumption in the future. The increase in capital implies that current and future output will be positively correlated. Quantitatively, the positive autocorrelation of output will require that technology shocks are strongly positively autocorrelated. Finally, there is no problem in accounting for the volatility of output. For, it is standard practice to set the variance of the technology shock so as to equate the volatility of output in the artificially created data to the volatility of output in the real data.[11]

With the exception of government spending, the major components of spending, income, and output also behave very similarly in all seven countries. Thus, consumption and investment are about sixty and twenty percent of GNP/GDP (Parts (1) and (2) of Table 1B). Fixed investment is relatively three to four times more variable than consumption. Consumption and investment are strongly procyclical and coincidental. Consumption leads income in France only, while equipment investment seems to be lagging in Canada and in the US. Consumption's share of GNP/GDP is strongly countercyclical and investment's share of GNP/GDP is strongly procyclical. These results are also consistent with the findings of BK.

Qualitatively, these facts can easily be accounted for by the BRBC model. For, in the example just discussed, output will fluctuate more than consumption, implying that investment will fluctuate more than output. More importantly, there are several RBC models that can quantitatively account for these findings.[12]

The most variable component of investment and, indeed of GNP, is inventory investment.[13] This component fluctuates more than ten times as much as GNP/GDP and is procyclical. The BRBC model does not incorporate inventories. But, these findings can be accounted for by a slightly modified version of the RBC model. Christiano (1988) has explained both of these features of inventory investment. He allowed for employment and investment decisions to be made before and consumption and inventory decisions to be made after the technology shock is (fully) known. In this manner, when there is an unexpected technology shock inventory investment buffers consumption. And, when there is an expected technology shock, inventories and fixed investment may again be used to smooth consumption. Thus, inventory investment becomes procyclical and, as the residual of a smoothing process, very volatile.

Not surprisingly, given differences in preferences and institutions, government spending behaves differently in each country. In the United States it is 22 percent of GNP, more variable than GNP, contemporaneously uncorrelated and lags the GNP cycle by five quarters. In Canada, government final consumption is 23 percent of GNP, more variable than GNP, procyclical and lags the GNP cycle by three quarters. In Japan, government final consumption is 23 percent of GDP, more variable than GDP, procyclical, and coincidental or slightly leading. In Germany, government final spending is 20 percent of GDP, less variable than GDP, procyclical, and lags the GDP cycle by five quarters. In France, government final spending is 19 percent of GDP, less variable than GDP, procyclical, and leads the GDP cycle by four quarters. In the United Kingdom, government final spending is 22 percent of GDP, less variable than GDP, and uncorrelated with GDP at all lags/leads. Finally, in Italy government final spending is about 16 percent of GDP, less variable than GNP, countercyclical and lags the GNP cycle by about one quarter.

The BRBC model abstracts from government spending. But, a simple extension of this model with government goods partially substitutable for private goods (e.g., Barro (1990, Ch.12); Aiyagari, Christiano, and Eichenbaum (1990)) is consistent with the procyclicality of government spending. Intuitively, an increase, say, in government spending tends to reduce real wealth and, therefore, decrease consumption and leisure. Under the stated assumptions, the direct effect of government spending dominates the decrease in consumption and aggregate demand increases. Since the aggregate supply of labor also increases, the real wage rate will decrease and the real interest rate and aggregate output will increase. Aggregate consumption and aggregate investment will further decline, because of the crowding out. This decline will be greater for consumption and less for investment the more persistent is the increase in government spending, due to the consumption smoothing motive. Thus, aggregate output rises but, typically, by not as much as the increase in government spending (i.e., the pertinent multiplier is positive but less than one). This is consistent with our results, when the highest correlations are converted to multiplier units.[14]

The GNP/GDP shares of exports and imports in the United States is between 2.0 and 2.5 times smaller than the corresponding shares of the other six countries. Otherwise, the behavior of exports and imports is very similar in all seven countries. Exports and imports are more variable than consumption and GDP/GNP but less variable than investment. Exports are weakly or strongly (Canada and France) procyclical, but, typically, their cycle coincides with the GNP/GDP cycle. The exceptions are the United States and Japan, where exports lag output by two and four quarters respectively. Imports are strongly procyclical and their cycle coincides with the GNP/GDP cycle. The GNP/GDP share of exports does not have a stable pattern but the GNP/GDP share of imports is strongly procyclical or weakly procyclical (Germany) and its cycle coincides with the cycle of GNP/GDP.[15] This last finding implies that net exports are countercyclical. These findings are, again, consistent with those of BK and the earlier findings of Dellas (1986).

RBC models, as one good models, can only explain net exports. In addition, the BRBC model is a closed economy model. But, open economy versions of this model that feature country specific technology shocks and a perfect international credit market, can account for the above findings (Dellas (1986); Backus, Kehoe, and Kydland (1991)). In these models, international credit markets in the presence of idiosyncratic technology shocks tend to make consumption less and investment more variable than in the closed economy, respectively.[16] Moreover, in these models net exports are countercyclical. Intuitively, if an economy experiences a "good" technology shock it will invest more by borrowing in the international credit markets. Thus, net exports will go down while output rises. Further, the more persistent is the technology shock the stronger the underlying countercyclicality.

3.2 <u>Prices and Monetary Variables</u>

The stylized facts pertaining to prices and monetary variables are reported in Table 2. The comovements of GNP/GDP and the following variables: money stock as measured by M1, M2, and M3; interest bearing quasi-moneys as measured by M2-M1 and M3-M1; velocities of M1, M2, and M3; and prices (GNP/GDP deflator and CPI). As already mentioned, money does not have a clear cut pattern and its behavior varies both across countries and money stock definitions. Thus, apart from the facts that: (i) With the exception of M1 in the United Kingdom and, possibly, M1 and M2 in Italy, money stocks do not have a strong positive correlation with GNP/GDP at any lead or lag; (ii) With the exception of M3 for the United States, money stocks fluctuate more than real GNP/GDP; and (iii) Velocity measures fluctuate, in general, more than the corresponding money stocks; there are no other uniformities in the behavior of monetary variables.

In particular, in the United States we confirm the KP findings that M1 is weakly procyclical and weakly leading or coincidental with real GNP. The difference between M1 and M3 is more correlated with real GNP but otherwise its cycle has a similar phase relative

TABLE 2: PRICES AND MONETARY VARIABLES

Variable	Vol.	x_{t-5}	x_{t-4}	x_{t-3}	x_{t-2}	x_{t-1}	x_{t}	x_{t+1}	x_{t+2}	x_{t+3}	x_{t+4}	x_{t+5}
(1) M1 Volatility												
US	1.66	.00	.07	.15	.24	.29	.29	.20	.14	.09	.08	.08
Canada	2.25	.21	.31	.43	.50	.43	.24	.09	-.09	-.17	-.11	-.05
Japan	2.61	-.34	-.21	-.08	.03	.09	.10	.12	.11	.11	.10	.12
Germany	4.64	.17	.15	.14	.11	.03	-.00	-.05	-.17	-.17	.01	.02
France	2.64	.27	.31	.33	.32	.27	.12	.01	-.08	-.13	-.11	-.07
UK[3]	3.25	.47	.57	.63	.62	.51	.33	.13	-.07	-.26	-.35	-.35
Italy[4]	3.77	-.03	.10	.24	.38	.46	.42	.35	.22	.08	-.01	-.11
(2) M2												
US	NA											
Canada	2.93	-.50	-.51	-.48	-.41	-.27	-.08	.11	.28	.40	.46	.47
Japan	1.65	-.41	-.25	-.10	.05	.14	.18	.16	.13	.08	.03	.02
Germany[5]	2.63	-.26	-.17	-.10	.03	.12	.25	.35	.35	.35	.34	.29
France	5.00	.24	.29	.32	.33	.34	.27	.20	.15	.13	.15	.13
UK	3.97	-.34	-.25	-.19	-.11	-.07	-.03	-.03	-.00	-.02	-.03	-.02
Italy	2.09	.14	.27	.29	.48	.49	.39	.23	.04	-.11	-.21	-.30
(3) M3												
US	1.51	.13	.22	.31	.41	.47	.48	.41	.30	.17	.04	-.08
Canada	NA											
Japan	NA											
Germany	NA											
France	1.31	.36	.41	.46	.43	.36	.17	.04	-.08	-.18	-.19	-.17
UK	NA											
Italy	NA											
(4) M2-M1												
US	NA											
Canada	3.77	-.50	-.52	-.51	-.46	-.32	-.11	.10	.29	.43	.47	.47
Japan	1.40	-.36	-.22	-.07	.08	.17	.21	.18	.11	.01	.07	-.11
Germany	7.90	-.33	-.30	-.28	-.18	-.06	.09	.21	.29	.35	.35	.29
France	7.34	.22	.27	.30	.32	.35	.31	.26	.23	.23	.23	.19
UK	8.01	-.45	-.39	-.35	-.27	-.21	-.12	-.06	.02	.06	.07	.08
Italy	6.86	.09	.14	.13	.04	.00	-.02	-.03	-.12	-.15	-.12	-.06
(5) M3-M1												
US	1.97	.16	.23	.31	.38	.42	.42	.35	.26	.13	.00	-.12
Canada	NA											
Japan	NA											
Germany	NA											
France	1.17	.27	.30	.35	.31	.27	.15	.05	-.03	-.13	-.18	-.19
UK	NA											
Italy	NA											

TABLE 2 CONT.

Variable	Vol.	X_{t-5}	X_{t-4}	X_{t-3}	X_{t-2}	X_{t-1}	X_{t}	X_{t+1}	X_{t+2}	X_{t+3}	X_{t+4}	X_{t+5}
(6) Velocity M1												
US	2.02	-.21	-.16	-.09	.02	.16	.33	.33	.26	.17	.09	.01
Canada	2.44	-.26	-.15	-.05	.03	.18	.30	.31	.26	.17	.06	.05
Japan	3.30	-.06	-.01	-.05	-.04	.02	.14	.08	.06	.03	.00	-.08
Germany	5.00	-.23	-.12	-.08	-.00	.15	.31	.28	.35	.34	.14	.06
France	11.40	-.40	-.44	-.43	-.40	-.29	-.10	-.01	.05	.06	.02	-.02
UK	3.16	-.53	-.60	-.54	-.42	-.19	.20	.20	.29	.38	.36	.36
Italy	6.83	-.22	-.33	-.29	-.23	-.19	-.10	-.02	.07	.09	.03	.04
(7) Velocity M2												
US	NA											
Canada	2.34	.15	.18	.25	.34	.38	.35	.13	-.12	-.33	-.45	-.50
Japan	2.56	.00	-.06	-.08	-.05	.03	.17	.11	.11	.10	.08	.00
Germany	2.71	.12	.19	.19	.15	.11	.02	.01	-.06	-.14	-.36	-.40
France	9.60	-.36	-.40	-.40	-.39	-.34	-.22	-.17	-.13	-.12	-.15	-.14
UK	4.33	.29	.22	.25	.26	.30	.42	.27	.17	.10	.03	.02
Italy	10.20	-.26	-.35	-.30	-.17	-.08	.02	.06	.16	.17	.09	-.05
(8) Velocity M3												
US	1.68	-.11	-.11	-.10	-.05	.00	.07	.07	.07	.07	.07	.08
Canada	NA											
Japan	NA											
Germany	NA											
France	2.81	-.57	-.60	-.56	-.46	-.30	-.04	.03	.10	.12	.09	.06
UK	NA											
Italy	NA											
(9) Implicit GDP/GNP deflator												
US	.95	-.47	-.60	-.68	-.72	-.70	-.63	-.51	-.37	-.22	-.06	.08
Canada[6]	1.71	-.47	-.51	-.50	-.46	-.41	-.34	-.20	-.07	.04	.14	.21
Japan	1.84	-.36	-.46	-.51	-.52	-.48	-.43	-.34	-.21	-.10	-.01	.02
Germany	.97	-.32	-.35	-.34	-.28	-.24	-.15	.07	.23	.33	.35	.44
France	1.31	-.37	-.48	-.53	-.60	-.61	-.60	-.47	-.34	-.25	-.18	-.08
UK	2.33	-.09	-.22	-.34	-.45	-.54	-.57	-.48	-.39	-.23	-.09	.08
Italy	1.84	-.54	-.64	-.68	-.61	-.50	-.33	-.14	.04	.16	.18	.17
(10) CPI												
US	1.51	-.57	-.67	-.73	-.73	-.67	-.55	-.39	-.22	-.03	.15	.31
Canada	1.77	-.32	-.41	-.45	-.43	-.35	-.32	-.22	-.15	-.01	.05	.15
Japan	NC											
Germany	1.01	-.49	-.53	-.52	-.45	-.42	-.39	-.27	-.21	-.14	-.04	.05
France	1.61	-.44	-.57	-.63	-.64	-.61	-.55	.41	-.25	-.11	.03	.15
UK	2.81	-.06	-.22	-.25	-.37	-.38	-.43	-.36	-.31	-.15	-.08	.01
Italy	2.04	-.44	-.52	-.59	-.57	-.49	-.32	-.13	.03	.14	.21	.19

[3] 71Q2-89Q2, [4] 62Q1-89Q3, [5] M1 plus quasi-money, [6] 61Q1-89Q3.

to real GNP as M1. Velocities are weakly procyclical. In Canada, Italy, and the United Kingdom M1 is weakly procyclical and leading the GNP/GDP cycle. But, M2, except in Italy, and M2-M1 are contemporaneously uncorrelated with GNP/GDP and have a negative leading comovement vis a vis the latter. In the United Kingdom and Italy M2-M1 is especially volatile. In Japan M1 and M2 have a negative leading comovement with real GNP. In Germany M1 is uncorrelated, while M2 is lagging real GDP, as it would be implied by a money demand rather than money supply relation between these two variables. Finally, in France M1, M2, and M2-M1 are weakly procyclical and leading the GDP cycle. M3 and M3-M1 are also leading, and they are contemporaneously uncorrelated with GDP.

The figures for Japan and Germany can be accounted by the BRBC model where money is ignored (i.e., money may enter through the Quantity Theory formulation). The figures for the United Kingdom, Italy, and to a lesser extend for France and the United States can be accounted for by extensions of the BRBC model where money is allowed to play a role, in the sense of affecting real variables. For example, in the cash in advance models of Cooley and Hansen (1989) and the Lucasian monetary misperceptions and the transaction costs or money-in-the-utility-function models of Kydland (1991). In these models, where money is not neutral, the predicted effects of money on output and employment are positive but relatively small. Further, the evidence for a positive leading comovement between M3-M1 and real GNP/GDP in the case of France and the United States can be accounted by extensions of the BRBC model that allows for institutional credit arrangements to affect real variables (Imrohoroglu and Pescott (1991)). The channel money affects real variables in these models is the real interest rate. That is, money and real interest rates are negatively related. There is some evidence for this mechanism in the negative and leading comovement of real interest rate and real GNP/GDP for all countries (Table 3).

The figures for Canada cannot be easily interpreted. First, there is a difficulty with the very different patterns of M1 and M2, and second, the strongly negative and leading comovement of M2-M1.

Also confirming the KP finding for the United States and the BK findings for post WWII Canada, Germany, Italy, Japan, the United Kingdom, and the United States, we find that in all seven countries both the GNP/GDP deflator and the CPI are countercyclical and leading GNP/GDP in most cases.[17,18]

The BRBC can easily account for a negative correlation between output and prices, as technology shocks shift the aggregate supply of output up and down a relatively stable downward-sloping aggregate demand.[19] In fact, the countercyclicality of prices and generally the weak correlation between money and output can be consistent with the RBC models with non-neutral money as well as the Quantity Theory. However, the Quantity Theory scenario would require a very low variability of velocity. Actually, even in the United States and Canada, where we have obtained the lowest values, the variability of velocity exceeds that of real GNP fluctuations.

As already mentioned in the introduction we examined the sensitivity of these findings to the detrending procedure. The results are in Appendix B. Both the fact that money does not strongly lead output and the fact that prices are countercyclical remain robust.[20]

3.3 The factors of production

Labor input, measured both in terms of workers and in terms of total hours, is procyclical in all countries and considerably less variable than output at the aggregate (Table 3), industry (Table 4), and manufacturing (Table 5) levels. Moreover, hours per worker, whenever available, are also procyclical, leading or coincidental, and less variable than employment. These facts are consistent with the KP findings for the US economy. Further as in KP, we find that in most cases employment lags output. In the aggregate economy of the United States, Canada, Germany and France, employment lags by about a quarter, in Italy and the United Kingdom employment lags by about two quarters, while in Japan is roughly coincidental. In this last case, however, the correlations are weak. At the industry level, employment lags by about one quarter in the United States, by about two quarters in Germany and France, and by three quarters in Italy. And, finally, at the manufacturing level employment lags by one quarter in the United States and Canada and by two quarters in Japan, Germany and United Kingdom.

In general, however, we do not find productivity leading output, but in most cases it is coincidental. The only cases where productivity is leading in terms of hours is in the United States industry and manufacturing, confirming indirectly KP, and German manufacturing. Further, the only cases where productivity in terms of employment is leading are in the United States industry and manufacturing.

The relationship between the real wage rate and output differs from country to country. Thus, the real wage rate in manufacturing

TABLE 3: THE FACTORS OF PRODUCTION

Cross correlations of Real GNP with

Variable X	Volatility % s.d	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(1) Real	**GNP/GDP**											
USA	1.74	.01	.21	.41	.65	.85	1.0	.85	.65	.41	.21	.01
Canada	1.39	-.12	.04	.27	.51	.78	1.0	.78	.51	.27	.04	-.12
Japan	1.53	.02	.19	.38	.59	.78	1.0	.78	.59	.38	.19	.02
Germany	1.69	-.02	.23	.35	.46	.67	1.0	.67	.46	.35	.23	-.02
France	.90	-.06	.10	.30	.54	.77	1.0	.77	.54	.30	.10	-.06
UK	1.54	-.02	.07	.20	.37	.55	1.0	.55	.37	.20	.07	-.02
Italy	1.70	-.21	-.04	.22	.52	.80	1.0	.80	.52	.22	-.04	-.21
(2) Employment												
USA	1.05	-.11	.06	.24	.44	.65	.83	.88	.80	.66	.47	.27
Canada	1.25	-.35	-.21	.00	.22	.45	.67	.71	.59	.44	.37	.25
Japan	.68	-.03	.00	.06	.24	.26	.27	.19	.24	.18	.06	-.08
Germany[7]	1.02	-.26	-.11	-.08	.08	.15	.29	.30	.25	.17	.05	.07
France	.56	-.27	-.20	-.09	.13	.35	.60	.68	.61	.51	.40	.21
UK	1.00	-.28	-.19	-.09	.13	.26	.43	.51	.58	.55	.54	.46
Italy	.92	-.22	-.22	-.05	.03	.23	.35	.39	.40	.38	.24	.14
(3)=(1)÷(2) Productivity												
USA	1.04	.13	-.29	.45	.64	.76	.83	.53	.28	.02	-.13	-.25
Canada	1.10	.26	.29	.35	.39	.48	.52	.20	-.02	-.15	-.36	-.43
Japan	1.49	.09	.19	.36	.49	.68	.90	.72	.49	.31	.16	.04
Germany	1.13	-.09	-.03	.15	-.04	.15	.61	.09	-.08	.08	.01	-.21
France	.72	.13	.28	.45	.57	.69	.78	.43	.20	-.02	-.18	-.25
UK	1.41	.17	.21	.26	.29	.40	.76	.22	-.03	-.20	-.31	-.36
Italy	1.64	-.09	.08	.25	.53	.70	.85	.61	.32	.01	-.18	-.30

(6) Real interest Rate[8]

US	2.39	.05	-.33	-.28	-.21	-.12	.01	.11	.17	.19	.21	.21	.19
Canada	2.45	.05	-.33	-.30	-.23	-.11	.04	.17	.19	.17	.16	.12	.07
Japan	2.30	.08	-.29	-.28	-.21	-.14	-.04	.08	.19	.24	.29	.28	.25
Germany	2.32	.05	-.44	-.37	-.20	-.01	.16	.28	.47	.57	.57	.49	.42
France	2.10	.08	-.22	-.24	-.21	-.19	-.14	-.07	.00	.07	.12	.14	.15
UK	2.76	.06	-.24	-.20	-.14	-.07	-.01	-.03	.05	.08	.12	.07	.02
Italy	6.23	.11	-.24	-.22	-.18	-.10	-.04	.04	.09	.12	.11	.08	.06

[7] 81Q1-89Q2

[8] The real interest rate, r, is evaluated as r(t) = (1+(i(t)/100))*(p(t)/p(t+1 where i is the nominal rate (yield on long-term government bonds) and p is the GNP/GDP deflator. In this case data have been just logged, not filtere

TABLE 4: THE FACTORS OF PRODUCTION IN INDUSTRY

Cross correlations of real GNP/GDP with

Variable X	Volatility % s.d	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(1) Industrial Production Index												
US	3.70	-.03	.14	.35	.57	.79	.93	.85	.67	.44	.20	.00
Canada	3.79	.03	.15	.36	.60	.77	.84	.69	.45	.17	-.07	-.27
Japan	4.07	-.09	.04	.23	.44	.62	.75	.76	.66	.48	.28	.03
Germany	3.06	-.01	.24	.40	.53	.72	.84	.71	.57	.37	.09	-.09
France	2.70	-.08	.06	.27	.52	.72	.85	.70	.49	.22	-.01	-.15
UK	2.85	-.08	.05	.27	.41	.58	.75	.61	.46	.28	.13	.02
Italy	3.58	-.13	.03	.23	.48	.72	.88	.65	.38	.10	-.20	-.36
Cross correlations of industrial production index with												
(2) Employment in Industry												
US[9]	2.73	-.31	-.11	.12	.38	.63	.82	.85	.77	.62	.43	.23
Canada	NA											
Japan	NA											
Germany	1.79	-.32	-.14	.04	.25	.48	.68	.80	.81	.74	.60	.46
France	0.72	-.43	-.41	-.32	-.12	.14	.44	.65	.74	.72	.55	.33
UK	NA											
Italy[10]	1.59	-.46	-.50	-.42	-.25	-.05	.14	.33	.43	.50	.48	.43
(3)=(1)/(2) Productivity in Industry												
US	2.05	.21	.41	.58	.70	.78	.75	.50	.20	-.05	-.27	-.46
Canada	NA											
Japan	NA											
Germany	2.35	.15	.32	.52	.64	.76	.83	.51	.22	-.02	-.25	-.45
France	2.47	-.14	.06	.35	.64	.85	.96	.70	.39	.04	-.23	-.36
UK	NA											
Italy	3.79	-.07	.14	.53	.52	.67	.90	.51	.24	-.05	-.27	-.45

[9] 65Q1-89Q3

[10] 62Q1-88Q4

TABLE 5: THE FACTORS OF PRODUCTION IN MANUFACTURING

Cross correlations of real GNP/GDP with

(1) Production Index in Manufacturing

US	4.09	.00	.18	.38	.60	.81	.93	.85	.66	.43	.19	-.01
Canada	3.95	-.03	.12	.36	.62	.81	.88	.73	.48	.21	-.03	-.21
Japan	4.11	-.09	.04	.23	.44	.62	.75	.76	.65	.48	.27	.03
Germany	3.15	-.01	.20	.37	.51	.71	.85	.72	.58	.39	.13	-.06
France	3.02	-.09	.06	.28	.53	.73	.87	.71	.50	.23	.01	-.17
UK	NA											
Italy	3.92	-.13	.02	.21	.46	.70	.87	.63	.37	.09	-.20	-.36

Cross correlations of manufacturing production index with

(2) Employment in Manufacturing

US	2.72	-.32	-.15	.09	.37	.67	.90	.93	.81	.63	.41	.20
Canada	3.35	-.36	-.28	-.11	.07	.29	.44	.50	.44	.38	.28	.25
Japan	1.82	-.32	-.27	-.17	.02	.15	.30	.39	.43	.42	.35	.27
Germany	2.21	-.32	-.16	.03	.26	.50	.72	.85	.87	.81	.68	.51
France	NA											
UK	1.86	-.38	-.27	-.08	.09	.29	.54	.73	.75	.68	.57	.45
Italy	NA											

(3) Hours per worker in Manufacturing[11]

US	.94	.18	.38	.57	.72	.83	.80	.50	.16	-.12	-.29	-.38
Canada	1.72	.09	.15	.21	.26	.31	.28	.17	.03	-.03	-.12	-.16
Japan	1.10	.26	.46	.64	.73	.73	.64	.39	.08	-.23	-.48	-.60
Germany	1.14	.03	.20	.37	.57	.74	.79	.72	.49	.23	.00	-.21
France	NA											
UK	1.22	.11	.12	.26	.36	.47	.69	.46	.28	.04	-.22	-.33
Italy	NA											

(4)=(2)x(3) Total hours in Manufacturing

US	3.32	-.21	-.02	.23	.51	.78	.97	.90	.71	.48	.26	.06
Canada	3.14	-.38	-.25	-.02	.22	.43	.59	.59	.48	.31	.18	.16
Japan	1.96	-.15	.00	.19	.39	.54	.63	.58	.44	.26	.06	-.09
Germany	2.98	-.22	-.05	.16	.41	.66	.84	.90	.84	.69	-.51	.30
France	NA											
UK	2.41	-.24	-.15	.06	.24	.46	.75	.78	.71	.54	.32	.17
Italy	NA											

(5)=(1)/(2) Productivity in Manufacturing in terms of employment

US	2.00	.31	.49	.65	.78	.86	.81	.50	.17	-.09	-.28	-.40
Canada	3.63	.17	.31	.46	.60	.70	.72	.51	.27	.05	-.19	-.39
Japan	3.97	-.09	.15	.43	.68	.85	.90	.74	.47	.15	-.14	-.36
Germany	2.20	.25	.41	.57	.64	.69	.71	.35	.03	-.22	-.44	-.59
France	NA											
UK (4)/(8)	2.46	.17	.26	.40	.55	.67	.78	.34	.06	-.16	-.37	-.45
Italy	NA											

TABLE 5 CONT.

Cross correlations of manufacturing production index with

Variable X	Volatility % s.d	X t-5	X t-4	X t-3	X t-2	X t-1	X t	X t+1	X t+2	X t+3	X t+4	X t+5
(6)=(1)÷(4) Productivity in Manufacturing in terms of hours												
US	1.22	.37	.51	.63	.72	.76	.72	.44	.16	-.06	-.24	-.36
Canada	3.32	.15	.26	.39	.52	.62	.64	.47	.27	.08	-.14	-.35
Japan	3.25	-.20	.03	.31	.58	.79	.88	.77	.54	.27	.00	-.24
Germany	1.76	.29	.39	.47	-.44	-.39	.38	-.03	-.29	-.42	-.56	-.60
France	NA											
UK	1.89	.15	.25	.33	.46	.54	.55	.13	-.13	-.26	-.36	-.39
Italy	NA											
(7) Real Hourly wages in manufacturing[11]												
US	0.90	.19	.29	.36	.42	.49	.49	.37	.24	.13	-.00	-.09
Canada	1.61	.36	.27	.11	-.06	-.17	-.25	-.30	-.26	-.24	-.22	-.24
Japan	2.46	-.11	-.01	.08	.15	.21	.24	.25	.24	.22	.19	.18
Germany	1.12	-.15	-.26	-.22	-.20	-.15	-.10	-.12	-.00	.14	.23	.25
France	0.75	-.27	-.40	-.49	-.53	-.50	-.41	-.26	-.15	.00	.19	.29
UK	1.61	-.13	-.02	.07	.21	.35	.46	.28	.16	.00	-.04	-.05
Italy	1.93	-.18	-.17	-.11	-.13	-.12	-.11	-.22	-.15	-.00	.10	.04

[11] Earnings divided by the GNP/GDP deflator. Data for France and Italy are hourly rates. The sample for UK is 63Q1-89Q1.

is procyclical in the United States and the United Kingdom, confirming the Dunlop/Tarshis evidence, and in Japan; countercyclical in Canada and France; and contemporaneously uncorrelated with output in Germany and Italy.

As already mentioned, the real interest rate is leading countercyclically in all cases and is more volatile than real GNP/GDP. A reduction in the real rate seems to stimulate the economy in about one year. In some cases (Germany, Japan) the correlations between the real rate of interest and GNP/GDP become positive.

The procyclicality of total hours, productivity, and the real wage rate is very much consistent with the BRBC, where "good" ("bad") technology shocks increase (decrease) the physical marginal product of labor, employment, the real wage rate, and output. The procyclicality of total hours, and the countercyclicality of productivity and the real wage rate can be accounted for in two ways. First, if one allows for government and/or preference shocks that affect labor supply decisions as in the model of Aiyagari, Christiano, and Eichenbaum (1989) and Christiano and Eichenbaum (1989), discussed above. Second, in the "price shocks" type model of Kydland(1991). It follows that by combining technology and preference or government shocks and/or price shocks in an RBC model one can explain a whole array of alternative cyclical properties of productivity and real wages. Unfortunately, we know of no quantitative evidence for these properties.

The relationship between the real rate of interest and output can also be accounted for, as explained in Subsection 4.2. However, it should be emphasized that this relationship may be plagued by several measurement errors. Most importantly we do not use a short-term nominal rate and we measure the expected rate of inflation by its realized counterpart (See Footnote 8 in Table 3).

The major discrepancies between the RBC model and the evidence presented above are in labor dynamics. First, employment variations seem to be relatively too small and hours per worker variations seem to be relatively too large to be accounted for by existing versions of the RBC model.[21] Second, employment lags output everywhere while hours per worker are coincidental or leading, contrary to RBC formulations where employment adjustments are explicitly or implicitly synchronous to output.

Now, what we mean by "relatively," above is vis a vis the current versions of the RBC model. That is, although the variability of total hours predicted by the indivisible-labor (Rogerson(1988)-Hansen (1985)) and work week-of-capital (Kydland and Prescott (1988)) versions of the RBC model is about right, the variability of the components of total hours is not. In these models as well as in the BRBC and the time-to-build (Kydland and Precott (1982)) version of the RBC, hours per worker are fixed. Thus, all the variability in these models is due to variability in employment. Moreover, models that allow for hours-per-worker variability seem to grossly underpredict this variation (i.e., in the straight-time/over-time model of Hansen and Sargent (1988) and in the model of Kydland and Prescott (1991)).[22] Moreover, with the exception of the last model, the above models fail to recognize the lagging employment adjustment. This is also the case in Burnside, Eichenbaum, and Rebelo (1990), where time varying effort is introduced in the indivisible-labor version of the RBC model to capture labor hoarding phenomena. For in this model, firms have to make employment decisions before and effort decisions after technology shocks materialize. This implies that employment is set before output is set, although employment will not fluctuate as much as output.[23]

A modification of the BRBC that could, in principle, account for these findings still implies some type of labor hoarding; that is, a situation where firms find relatively more costly to adjust employment rather than hours per worker, so that they have an incentive to smooth employment over the business cycle and utilize labor more intensively in expansions and less intensively in contractions.[24] There are several other reasons for this relative difference. In general, recursive production technologies whereby the production process is such that current output depends on past inputs and their current utilization rates (Cassing and Kollintzas (1991)). If employment is such an input, then it will also tend to lag output. Also this difference may be accounted for by adjustment costs due to institutional factors guiding search by heterogeneous workers and union behavior. This scenario is consistent with survey data (Fay and Medoff (1985)) and time series data (Bernanke and Parkinson (1991)) in US manufacturing and elsewhere. Further, they are consistent with the fact that employment in the European countries and Japan fluctuates relatively less than in the North American countries and total hours fluctuate considerably more than employment. This is because it is generally believed that labor institutions in Europe and Japan create more potent adjustment costs and flow of information impediments. Thus, labor hoarding type behavior may be more important in the European countries and Japan.

4. CONCLUDING REMARKS

In this paper we examined whether the RBC model can account for the pertinent stylized facts of business cycles in the G7, in a manner similar to Kydland and Prescott's (1990) study for the United States. Our data are stationary cyclical deviations obtained from filtering as in Hodrick and Prescott (1980) a selected number of OECD-MEI quarterly time series. Our data set does not fully match that of Kydland and Prescott both in terms of time coverage and available data series so that our results for the US can differ from theirs.

Real GNP/GDP is persistent in all countries. All components of expenditure are procyclical. Consumption expenditure is less volatile than GNP/GDP which in turn is much less volatile than investment expenditure. Inventory investment is by far the more volatile component of investment expenditures. Imports and exports fluctuate less than consumption and more than investment expenditures. Government consumption behaves differently in each country.

Prices are leading countercyclically everywhere. Money stock does not strongly lead output, but the evidence is different from country to country. A similar finding holds true for various proxies of credit aggregates.

The stylized facts pertaining to the components of spending and monetary variables confirm the results of Kydland and Prescott for the United States and of Backus and Kehoe (1989) for Canada, Germany, Italy, Japan, United Kingdom, and the United States. Further, we provide evidence that these results do not depend on the data filtering method.

Employment, measured both in terms of workers and in terms of total hours, is procyclical, lagging, and considerably less variable than output at the aggregate, industry, and manufacturing level. Moreover, hours per worker, are also procyclical, coincidental or leading and less variable than employment. Real wages are procyclical in the United States, Japan and the United Kingdom and countercyclical in the other countries. Finally, there is evidence that real interest rates are leading countercyclically output, confirming conventional wisdom.

With the exception of the variabilities of hours per worker and employment and the lagging employment, which we take to indicate labor hoarding, we provide some simple intuitive explanations showing how current RBC models can account for these findings. Further, we conjecture that, in principle it is possible to construct RBC models that can account for the variabilities of hours per worker and employment and the lagging employment findings. These models should incorporate adjustment costs and variable employment utilization. Adjustment costs may reflect technological or institutional factors guiding search by heterogeneous workers and union behavior.

Finally, it should be mentioned, that we attempted to match specific stylized facts with particular RBC models. Thus, we do not know whether there is a synthesis of these models that could account simultaneously for all the stylized facts examined in this paper.

FOOTNOTES

1. The stylized facts of business cycles were in the forefront of research in macroeconomics in the first half of the twentieth century. Leading piece of this literature is the work of Burns and Mitchell (1946). A survey of more recent work on this spirit is Zarnowitz (1985).

2. An important early paper with a similar aim is Long and Plosser (1983).

3. See Plosser (1989) and McCallum (1990) for illuminating surveys.

4. An exception is the work of Backus and Kehoe (1989), who seem to be the first to have examined the properties of business cycle fluctuations in many countries from a real business cycles perspective.

5. A general discussion of the implications of the nature of secular, cyclical, and seasonal fluctuations for the econometric modelling of smoothed trend can be found in Singleton (1988).

6. An excellent survey on the controversial topic of stochastic trends is Diebold and Nerlove (1990). See also DeJong and Whiteman (1991).

7. King, Plosser, and Rebelo (1988) emphasized this point and chose to represent trend via deterministic exogenous labor augmenting technical change.

8. In a certain sense there are deeper problems with studying the decomposition of a variable to its growth and trend components without explicitly specifying a model with a stable steady state growth path to guide this decomposition.
   Generalized versions of the Cass-Koopmans model may not have such paths. In fact, Boldrin and Montrucchio (1986) have shown that such models may exhibit all kinds of complicated dynamics, including chaotic.

9. The results of Appendix D cannot be directly compared, say, with those studies showing that consumption and income are cointegrated, since our data deal with HP-trended variables and with real GNP/GDP rather than disposable income.

10. The cutoff point .2 was chosen because it roughly corresponds to the required value to reject in our samples the null hypothesis that the correlation coefficient is zero at the 5% level of significance in a two sided t-test.

11. The necessary magnitude of this variance, however, is a controversial issue. See Summers (1986), McCallum (1989), Burnside, Eichenbaum and Rebelo (1990), and Cassing and Kollintzas (1991). This issue will be taken up later.

12. See, e.g., Prescott (1986), Kydland and Prescott (1982) and Hansen (1985).

13. The HP filter was applied to logged inventory investment data, which sometimes is negative, by adding a sufficiently large positive constant.

14. Aiyagari, Christiano, and Eichenbaum (1990) and Christiano and Eichenbaum (1990) show that the multiplier can be greater than one.

15. These findings seem to suggest that international interdependence may be an important source of fluctuations. But Canova and Dellas (1992) who looked into this issue found little evidence for that. Moreover, their results are very sensitive to the detrending method utilized.

16. Backus, Kehoe, and Kydland (1990) report significant differences between their model economy and the US economy. Most seriously, in the model foreign output and domestic output are less correlated than foreign and domestic consumption. In the data the opposite is true.

17. This stylized fact for the U.S. has been confirmed recently in an extensive study by Cooley and Ohanian (1991).

18. This fact along with that on the comovement of money and GNP/GDP are contrary to common beliefs (See, e.g., Bernanke (1986, p.76), Mankiw (1989 p.81 and p.88)) and has been used to criticize the BRBC model.

19. Visualizations of demands and supplies in the RBC framework are not particularly helpful and may be misleading, but in this case the demand/supply visualization seems appropriate.

20. This goes contrary to the Eichenbaum and Singleton (1986) findings, where the detrending method is crucial for the money-output causality.

21. See Kydland and Prescott (1991, Tables 3.1 and 3.2).

22. The Kydland and Prescott (1991) model can account for a .24% variation in hours per worker while the corresponding variation in the US that they report for 1954Q1-1988Q2 is .56%.

23. The primary motivation behind the Burnside, Eichenbaum, Rebelo (1990) paper is to show that the importance of the technology shock ("Solow residual") to explain business cycle fluctuations is reduced once one allows for labor hoarding

type behavior.

24. The model of Kydland and Prescott (1991) can be thought of an RBC model, where firms rather than households are facing employment adjustment costs.

REFERENCES

Aiyagari, S.R., Christiano, L.J., and Eichenbaum, M., (1990): "The output,employment, and interest rate effects of government consumption," NBER Working Paper No. 3330.

Backus, D. K., and Kehoe, P. J., (1989): "International evidence on the historical properties of business cycles," Working Paper 402R, Federal Reserve Bank of Minneapolis.

Backus, D. K., Kehoe, P. J., and Kydland, F.E., (1991): "International real business cycles," Working Paper 426R, Federal Reserve Bank of Minneapolis.

Barro, R.J., (1990): Macroeconomics. New York: John Wiley.

Benhabib, J., Rogerson R., and Wright R.,: "Homework in Macro-economics: Household Production and Aggregate Fluctuations".

Bernanke, B.S., (1986): "Alternative explanations of the money-income correlation." In K. Brunner and A. Meltzer, eds., Real Business Cycles, real exchange rates and actual policies, Carnegie Rochester Conference Series on Public Policy 25. Amsterdam: North-Holland.

Bernanke, B.S., and Parkinson, M.L., (1991): "Procyclical labor productivity and competing theories of the business cycle: Some evidence from interwar U.S. manufacturing industries," Journal of Political Economy, 99, 439-459.

Boldrin, M., and Montrucchio, L. (1986): "On the intderterminacy of capital accumulation paths," Journal of Economic Theory, 40, 26-39.

Brock, W.A., and Mirman L.J. (1972): "Optimal economic growth and uncertainty: the discounted case," Journal of Economic Theory, 4, 479-513.

Burns, Arthur F. and Mitchell, Wesley C. 1946. Measuring business cycles. New York: National Bureau of Economic Research.

Burnside, C., Eichenbaum, M., and Rebelo, S. (1990): "Labor hoarding and the business cycle," NBER Working Paper No.3556.

Canova, F., and Dellas, H., (1992): "Trade interdependence and the international business cycle," Journal of International Economics, forthcoming.

Cass, David. 1965. Optimum growth in an aggregative model of capital accumulation. Review of Economic Studies 32, 233-240.

Cassing, S., and Kollintzas, T., (1991): "Recursive factor of production interrelations and endogenous cycling," International Economic Review, 32, 417-440.

Christiano, L.J., (1988): "Why does inventory investment fluctuate so much?" Journal of Monetary Economics, 21, 247-280.

Christiano, L.J., and Eichenbaum, M.,(1990): "Is theory really ahead of measurement? Current real business cycle theories and aggregate labor market fluctuations," NBER Working Paper No. 2700.

Cogley, T., (1990): "Spurious business cycle phenomena in HP filtered time series." Manuscript, University of Washington.

Cooley, T.F., and Hansen, G., (1989): "The inflation tax in a real business cycle model," American Economic Review, , 733-748.

Cooley, T.F., and Ohanian, L.E., (1991): "The cyclical behavior of prices," Journal of Monetary Economics, 28, 25-60.

Dellas, H., (1986): "A real model of the world business cycle," Journal of International Money and Finance, 5, 381-394.

DeJong, D.N., and Whiteman, C.H., (1991): "Reconsidering "Trends and random walks in macroeconomic time series," Journal of Monetary Economics, 28, 221-254.

Eichenbaum, M., (1991): "Real business cycle theory: Wisdom or whimsy?" Journal of Economic Dynamics and Control, 15, 607-626.

Eichenbaum, M., and Singleton, K., (1986): "Do equilibrium real business cycle models explain post-war U.S. business cycles?" in S. Fisher, ed.,NBER Macroeconomics Annual 1986. Cambridge: The MIT Press.

Engle,R.F., and Granger, C.W.J., (1987): "Co-integration and error correction: Representation, estimation, and testing," Econometrica, 55, 251-276.

Fay, J. and Medoff, J., (1985): Labor input over the business cycle, American Economic Review 75, 638-55

Hall, R.E., (1989): Invariance Properties of Solow's Productive Residual, NBER Working Paper # 3034.

Hansen, G.D., (1985): "Indivisible labor and the business cycle," Journal of Monetary Economics, 16, 309-28.

Hansen, G.D., and Sargent, T.J., (1988): "Straight time and over-time in equilibrium," Journal of Monetary Economics, 21, 281-308.

Harvey, A.C., and Jaeger, A.,: "Detrending, Stylized Facts and the Business Cycle", Discussion Paper No. EM/91/230, Suntory - Toyota International Center for Economics and Related Disciplines. June 1991.

Hodrick, R.J., and Prescott, E.C., (1980): Post-war US business cycles: an empirical investigation. Manuscript, Carnegie - Mellon Univercity.

Imrohoroglou A., and Prescott E.C., (1991): "Evaluating the Welfare Effects of Alternative Monetary Arrangements", Federal Reserve Bank of Minneapolis Quarterly Review, Summer, 3-10.

King, R.G., and Rebelo, S.T., (1988): Low frequency filtering and real business cycles. Manuscript. Univercity of Rochester.

King, R.G., Plosser, C.I., and Rebelo, S., (1989): "Production, Growth and Business Cycles: I. The Basic Neoclassical Model," Journal of Monetary Economics, 21, 195-232.

Koopmans, T.C., (1965): "On the concept of optimal growth." In The Econometric Approach to Development Planning. Chicago: Rand McNally.

Kydland, F.E., (1989): "The role of money in a business cycle model," Discussion Paper 23, Institute for Empirical Macroeconomics, Federal Rererve Bank of Minneapolis.

Kydland, F.E., and Prescott, E. C., (1982): "Time to build and aggregate fluctuations," Econometrica, 50, 1345-70.

Kydland, F.E., and Prescott, E.C., (1988): "The workweek of capital and its cyclical implications," Journal of Monetary Economics ,21, 343-60.

Kydland, F.E., and Prescott, E.C., (1990): "Business cycles: Real facts and a monetary myth," Federal Reserve Bank of Minneapolis Quarterly Review ,Spring, 3-18.

Kydland, F.E., and Prescott, E.C., (1991): "Hours and employment variation in business cycle theory," Economic Theory, 1, 63-81.

Long, J.B., and Plosser, C.I., (1983): "Real business cycles," Journal of Political Economy, 91, 1345-1370.

Lucas, R.E.,Jr., (1977):"Understanding business cycles," in K. Brunner and A.H. Meltzer,eds,Stabilization of the domestic and international economy, Carnegie-Rochester Conference Series on Public Policy 5. Amsterdam: North-Holland.

Mankiw, G.N., (1989): "Real business cycles: A new Keynesian perspective," Journal of Economic Perspectives, 3, 79-90

McCallum, B.T., (1989): "Real business cycles," in R.J. Barro, ed., Modern Business Cycle Theory. Cambridge: Harvard University Press.

Plosser, C.I., (1989): "Understanding real business cycles," Journal of Economic Perspectives, 3, 51-79.

Plosser, C.I., (1990): "Money and business cycles: A real business cycle interpretation", NBER Working Paper No. 3221.

Prescott, E.C., (1986): "Theory ahead of measurement," Federal Reserve Bank of Minneapolis Quarterly Review, Fall, 9-22.

Rogerson, R., (1988): "Indivisible labor, lotteries, and equilibrium," Journal of Monetary Economics ,21, 3-17.

Singleton, K.J., (1988): "Econometric issues in the analysis of equilibrium business cycle models," Journal of Monetary Economics, 21, 361-386.

Solow, R.M., (1956): "A contribution to the theory of economic growth," Quarterly Journal of Economics, 70, 65-94.

Summers, L.H., (1986): "Some skeptical observations on real business cycle theory," Federal Reserve Bank of Minneapolis Quarterly Review, Fall, 23-27.

APPENDIX A: THE HODRICK-PRESCOTT FILTER

Let:

$\tau=(\tau_t)_{t=1}^{T}$ denote the smoothed trend of a series $x=(x_t)_{t=1}^{T}$. Then, according to the HP filter this trend is obtained as the solution to the following problem:

$$\min_{\{\tau_t\}_{t=1}^{T}} \sum_{t=1}^{T}(x_t-\tau_t)^2 \tag{1}$$

$$\text{s.t.} \quad \sum_{t=2}^{T-1}[(\tau_t-\tau_{t-1})-(\tau_{t+1}-\tau_t)]^2 \leq \Lambda \qquad ;\Lambda\epsilon R_+; \tag{2}$$

That is, the smooth trend component is obtained by minimizing the sum of squared differences from the data subject to the constraint that the sum of the squared second differences be less than an appropriate bound Λ. The smaller is Λ the smoother is the trend path and when Λ is zero the smooth trend converges to the least squares trend. Problem (1) and (2) is equivalent to the following unconstrained problem:

$$\min_{\{\tau_t\}_{t=1}^{T}} \sum_{t=1}^{T}(x_t-\tau_t)^2 + \lambda\sum_{t=2}^{T-1}[(\tau_t-\tau_{t-1})-(\tau_{t+1}-\tau_t)]^2 \qquad ;\lambda\epsilon R_+; \tag{3}$$

for an appropriate value of the Lagrange multiplier λ. Now, the larger is λ the smoother is the trend path and as λ goes to infinity the smoothed trend converges to the least squares trend. Thus, τ can be obtained from x by means of the linear transformation:

$$\tau = A\ x \tag{4}$$

where A is a TxT matrix the coefficients of which are determined by the first order necessary conditions for a solution to the preceding problem and, of course, depend on λ. The value of λ that produces the "right" degree of smoothness for quarterly seasonally adjusted US data, according to Hodrick and Prescott(1980) is around 1600. This value of λ is consistent with the "prior view that a five percent cyclical component is moderately large as is one-eighth of one percent change in the rate of growth in a quarter."

Then, the business cycle component of x, $\kappa=\{\kappa_t\}_{t=1}^{T}$, can be obtained as:

$$\kappa_t = x_t - \tau_t \tag{5}$$

There are a number of alternative ways to look at this filter (Prescott (1990)). First, in the limit the τ's can be obtained as the solution to the fourth order difference equation:

$$\tau_{t+2}-4\tau_{t+1}+(6+\lambda)\tau_t-4\tau_{t-1}-\tau_{t-2}=x_t/\lambda \tag{6}$$

The solution to this equation is the doubly-infinite sequence:

where the α's depend on the value of the Lagrange multiplier λ.

$$\tau_t=\sum_{j=-\infty}^{\infty} \alpha_{|j|}\, x_{t-j} \tag{7}$$

Clearly, then, the smoothed trend component of the data is a time-invariant symmetric linear filter. And, King and Rebelo (1990) have shown that any stochastic process which is trend stationary under fourth differencing can be rendered stationary under this filter. Thus, one may view the HP decomposition procedure as generating a stationary component for any trended process under fourth differencing.

It has been reported that from a practical point of view the results are very similar with those from a high pass band filter eliminating all frequencies of 32 quarters (eight years) or greater.

APPENDIX B: THE DESEASONALIZATION PROCEDURE

Let Y_t be an unadjusted series and Y_t^s its s.a. counterpart in a quarterly data set. Clearly, we cannot simply obtain the s.a. series by subtracting the portion of Y_t explained by the usual three dummies, as in:

$$Y_t = \text{constant} + \sum_{i=1}^{3} b_i D_{it} + Y_t^s \tag{8}$$

since the s.a. series corresponds in this case to the OLS disturbances which have a zero mean while seasonal correction should be inter alia mean-preserving. Thus, it is customary to introduce in (8) a polynomial trend that should include higher order terms to approximate the typical MA filters. Then,

$$Y_t = \alpha_0^{*} + \sum_{i=1}^{h} \alpha_i T^i + \sum_{i=1}^{3} \beta_i^{*} D_{it} + v_t \qquad ;h\epsilon N. \tag{9}$$

However, the sum of β's in (9) cannot be zero since we have just 3 dummies vis a vis four seasons. Conversely, when we have an intercept and four dummies as in (10), seasonal deviations sum up to zero over the year but the model cannot be estimated:

$$Y_t = \alpha_0 + \sum_{i=1}^{h} \alpha_i T^i + \sum_{i=1}^{4} \beta_i D_{it} + v_t, \qquad \sum_{i=1}^{4} \beta_i = 0 \tag{10}$$

For, if we subtract from (9) $\Sigma\beta_i D_{it}$, again the mean of Y is not preserved by Y^s. To satisfy this requirement it is necessary to recover from eq.(10) the four seasonal dummies summing up to zero. This can be done by equating (9) to (11), a transformation of (10) where the last dummy is suppressed since $\beta_4=-(\beta_1+\beta_2+\beta_3)$:

$$Y_t = \alpha_0 + \beta_1(D_{1t}-D_{4t}) + \beta_2(D_{2t}-D_{4t}) + \beta_3(D_{3t}-D_{4t}) + v_t \tag{11}$$

This implies:

$$\alpha_0^* + \beta_i^* = \alpha_0 + \beta_i \qquad (i=1,2,3) \tag{12}$$

and

$$\alpha_0^* = \alpha_0 + \beta_4 \tag{13}$$

These equations can be solved to find the original intercept and seasonal coefficients:

$$\beta_4 = -(1/4)\sum_{i=1}^{3}\beta_i^* \tag{14}$$

$$\alpha_0 = \alpha_0^* - (1/4)\sum_{i=1}^{3}\beta_i^* \tag{16}$$

$$\beta_i = \beta_i^* - (1/4)\sum_{i=1}^{3}\beta_i^* \qquad (i=1,2,3) \tag{15}$$

Thus the s.a. series Y^s is obtained by subtracting from the unadjusted data the four seasonal factors found in (9) and (10):

$$Y_t^s = Y_t - \sum_{i=1}^{4}\beta_i D_{it} \tag{17}$$

Since in our case the trend is not approximated by a polynomial expansion but by the Hodrick and Prescott filter, the procedure we followed has five steps:

Step 1: Take first Y (not its log) and evaluate its smoothed trend Y^* using the Hodrick and Prescott filter.

Step 2: Regress Y on Y^*, an intercept and three seasonal dummies. (The coefficient of the smoothed trend should be one.)

Step 3: Obtain from (9) and (10) the four seasonal coefficients

Step 4: Obtain using (17) the s.a. series Y^s

Step 5: Take the log of Y^s and evaluate its smoothed trend using the HP filter.

Finally, seasonal adjustment was ignored when the joint significance of the dummy variables in Step 2 was less than a .05 level.

APPENDIX C: SENSITIVITY OF THE RESULTS TO ALTERNATIVE DETRENDING PROCEDURES[1]

AUTOCORRELATION IN REAL GNP/GDP AT GIVEN LAG (HP, TS, DS FILTERS)

USA	-1	-2	-3	-4	-5
HP	.85	.65	.41	.21	.01
TS	.94	.85	.73	.61	.49
DS	.27	.25	.02	.05	-.13
CANADA					
HP	.78	.51	.27	.04	-.12
TS	.91	.79	.07	.55	.44
DS	.24	.05	.09	-.02	-.05
JAPAN					
HP	.78	.59	.38	.19	.00
TS	.95	.90	.84	.77	.69
DS	.31	.35	.29	.28	.19
GERMANY					
HP	.67	.46	.35	.23	-.02
TS	.81	.66	.57	.46	.28
DS	-.09	-.09	.07	.24	-.19
FRANCE					
HP	.77	.54	.30	.10	-.06
TS	.84	.07	.50	.38	.25
DS	.23	.19	.05	.03	.11
UK					
HP	.54	.37	.20	.07	-.02
TS	.84	.74	.65	.56	.48
DS	-.24	.02	-.04	-.01	-.04
ITALY					
HP	.80	.52	.22	-.04	-.21
TS	.88	.72	.55	.39	.26
DS	.26	.20	-.01	-.09	-.08

[1] HP = Hodrick-Prescott filter; DS = first differences of logged variables; TS = Cycles are residuals from a qudratic trend (logged variables); RV= Relative variability (s.d. of GNP/GDP ÷ s.d. of the other variable).

CROSS-CORRELATIONS: HP, TS AND DS FILTERS
REAL GNP/GDP AND MONEY STOCK AT LAG

US	RV	-5	-4	-3	-2	-1	0	1	2	3	4	5
HP	1.05	.00	.07	.15	.29	.29	.29	.20	.14	.09	.08	.08
TS	1.39	.02	.04	.10	.19	.24	.25	.16	.11	.06	.05	.04
DS	0.97	-.07	-.07	-.09	.14	.16	.16	-.10	-.04	-.12	-.06	-.06
Canada												
HP	0.61	.21	.31	.43	.50	.43	.24	.09	-.09	-.17	-.11	-.05
TS	0.32	.14	.22	.29	.35	.37	.35	.36	.33	.33	.35	.37
DS	0.57	.09	.05	.05	.32	.26	.12	.05	-.08	-.20	-.03	.09
Japan												
HP	0.58	-.34	-.21	-.08	.03	.09	.11	.12	.11	.11	.10	.12
TS	0.57	-.43	-.34	-.25	-.15	-.07	.01	.07	.14	.20	.25	.31
DS	0.59	.13	.24	.26	.33	.35	.30	.31	.32	.32	.27	.30
Germany												
HP	0.37	.17	.15	.14	.11	.03	.00	-.05	-.17	-.17	.01	.02
TS	0.48	-.01	.10	.17	.19	.19	.19	.17	.13	.11	.13	.13
DS	0.38	-.12	.05	.05	.09	-.14	.06	.06	-.20	-.27	.28	.04
France												
HP	0.34	.27	.31	.33	.32	.27	.12	.01	-.08	-.13	-.11	-.07
TS	0.30	-.23	-.26	-.28	-.31	-.36	-.43	-.39	-.36	-.32	-.27	-.21
DS	0.35	.00	.04	.02	.08	-.20	-.06	-.03	-.05	-.05	.06	.00
UK[2]												
HP	0.51	.47	.57	.63	.62	.51	.33	.13	-.07	-.26	-.35	-.35
TS	0.68	.42	.50	.52	.49	.44	.38	.30	.24	.21	.18	.18
DS	0.79	.13	.27	.19	.13	.04	.15	-.14	-.11	-.04	-.08	-.07
Italy												
HP	0.45	.03	.10	.24	.38	.46	.42	.35	.22	.08	-.01	-.11
TS	0.25	-.36	-.30	-.24	-.19	-.18	-.14	-.12	-.11	-.10	-.08	-.07
DS	0.50	-.17	-.02	.05	.20	.25	.13	.11	.01	-.07	-.05	-.13

[2] 47Q1-88Q4

CROSS-CORRELATIONS: HP, TS AND DS FILTERS
REAL GNP/GDP AND IMPLICIT PRICE DEFLATOR AT LAG

US	RV	-5	-4	-3	-2	-1	0	1	2	3	4	5
HP	1.83	-.47	-.60	-.68	-.72	-.70	-.63	-.51	-.37	-.22	-.06	.08
TS	0.47	-.61	-.67	-.71	-.74	-.75	-.75	-.71	-.66	-.61	-.55	-.49
DS	1.40	-.27	-.30	-.33	-.34	-.28	-.30	-.19	-.20	-.11	-.08	-.12
Canada												
HP	0.81	-.47	-.51	-.50	-.46	-.41	-.34	-.20	-.07	.04	.14	.21
TS	0.33	-.43	-.42	-.41	-.39	-.36	-.34	-.26	-.19	-.12	-.05	.02
DS	1.13	-.30	-.27	-.27	-.18	-.18	-.32	-.10	-.05	-.06	-.02	-.02
Japan												
HP	0.83	-.37	-.46	-.51	-.52	-.48	-.43	-.34	-.21	-.10	-.01	.02
TS	0.57	-.80	-.80	-.79	-.78	-.77	-.73	-.67	-.60	-.53	-.46	-.39
DS	1.07	-.03	-.08	-.11	-.06	-.06	-.04	-.06	.07	.08	.20	.17
Germany												
HP	1.05	-.32	-.35	-.34	-.28	-.24	-.15	.07	.23	.33	.35	.44
TS	0.60	-.37	-.34	-.30	-.26	-.22	-.18	-.07	.02	.09	.15	.21
DS	1.80	-.09	-.06	-.10	.03	-.09	-.19	.10	.14	.13	-.06	.12
France												
HP	0.66	-.37	-.48	-.53	-.60	-.61	-.60	-.47	-.34	-.25	-.18	-.08
TS	0.37	-.53	-.60	-.65	-.70	-.74	-.78	-.66	-.54	-.42	-.33	-.23
DS	0.74	-.44	-.21	-.11	-.26	-.19	-.17	-.14	.01	-.02	-.04	-.06
UK												
HP	0.66	-.09	-.22	-.34	-.45	-.54	-.57	-.48	-.39	-.23	-.09	.08
TS	0.21	-.66	-.67	-.68	-.69	-.70	-.68	-.62	-.55	-.47	-.38	-.30
DS	0.92	-.08	-.12	-.09	-.14	-.16	-.27	-.01	-.17	-.03	-.12	-.01
Italy												
HP	0.92	-.54	-.64	-.68	-.61	-.50	-.33	-.14	.04	.16	.18	.17
TS	0.21	-.58	-.62	-.66	-.67	-.68	-.68	-.62	-.56	-.50	-.45	-.40
DS	0.73	-.31	-.35	-.41	-.30	-.32	-.25	-.20	-.08	-.03	-.12	-.12

CROSS-CORRELATIONS: HP, TS AND DS FILTERS
REAL GNP/GDP AND EMPLOYMENT AT LAG

US	RV	-5	-4	-3	-2	-1	0	1	2	3	4	5
HP	1.66	-.11	.06	.24	.44	.65	.83	.88	.80	.66	.47	.27
TS	2.02	-.06	.08	.22	.40	.57	.73	.77	.71	.61	.46	.31
DS	1.66	-.14	-.01	-.08	.04	.14	.69	.39	.27	.26	.11	.01
Canada												
HP	1.11	-.35	-.21	.00	.22	.45	.67	.71	.59	.44	.37	.25
TS	1.33	-.11	.03	.18	.35	.52	.66	.72	.71	.66	.64	.59
DS	1.12	-.05	-.09	-.07	.05	.09	.42	.39	.16	-.06	.19	-.11
Japan												
HP	2.26	-.03	.00	.06	.24	.26	.27	.19	.24	.18	.06	-.08
TS	4.18	.56	.56	.56	.60	.60	.59	.52	.48	.41	.32	.23
DS	1.42	-.06	.03	-.04	.22	.03	.13	-.10	.13	.08	.04	-.06
Germany												
HP	1.04	-.26	-.11	-.08	.08	.15	.29	.29	.25	.17	.05	.07
TS	1.61	-.02	.13	.03	.09	.09	.10	.15	.22	.07	-.11	-.08
DS	1.46	.10	.24	-.05	.16	.06	.17	.14	.23	.12	-.09	.13
France												
HP	1.61	-.27	-.20	-.09	.13	.35	.60	.68	.61	.51	.40	.21
TS	1.51	.19	.28	.39	.52	.68	.85	.82	.72	.58	.51	.38
DS	1.10	-.11	.02	-.04	.11	.05	.30	.35	.19	.14	.16	.18
UK												
HP	1.45	-.25	-.18	-.07	.15	.27	.44	.52	.57	.55	.52	.45
TS	1.34	.21	.29	.39	.52	.64	.74	.76	.75	.72	.68	.61
DS	2.26	-.03	.00	-.15	.20	-.02	.19	.11	.19	.05	.15	.06
Italy												
HP	1.84	-.22	-.22	-.05	.03	.23	.35	.39	.40	.38	.24	.14
TS	1.48	-.47	-.44	-.37	-.33	-.25	-.22	-.17	-.13	-.10	-.11	-.12
DS	1.13	.00	-.19	.06	-.17	.07	.08	.02	.03	.11	-.07	.02

APPENDIX D: PROPORTIONALITY OF GROWTH AND COINTEGRATION

The neoclassical growth model requires in steady-state that per capita output (Y/N), expenditure (X/N) and capital (K/N) grow at the same rate:

(1) $[(d/dt)(Y/N)]/(Y/N) = [(d/dt)(X/N)]/(X/N)$

By integrating (1) with respect to time we obtain:

(2) $\log(Y(t)) - \log(X(t)) = \theta$

where θ is a constant, showing the proportionality of growth between Y and X.

Without loss of generality, expression (2) can be estimated as the contemporaneous cointegrating equation:

(3) $y(t) = a + b\, x(t) + u(t)$

where y=log(Y) and x=log(X) are both nonstationary but where it may be found a constant b such that u(t) is a stationary cointegrating vector. The latter exists if y and x share a common stochastic trend.

Among the possible tests, Engle and Granger (1987) recommend the ADF (Augmented Dickey-Fuller) procedure which amounts to estimate the t-ratio for α in the auxiliary OLS regression:

(4) $$u(t)-u(t-1) = \alpha u(t-1) + \sum_{i=1}^{p} \blacksquare_i (u(t-i)-u(t-i-1)) + \epsilon(t)$$

where higher order terms are included to make the estimated residuals white noise. To reject the null hypothesis of no cointegration, α has to be negative and significantly different from zero. However, the relevant statistics does not have a t-distribution but has been tabulated in a Monte Carlo study by Engle and Granger. The reported critical values for the two variable case with 100 observations and p=4 are: -3.77 (1%),-3.17 (5%) -2.84 (10%).

In the following table we report the 't-ratios' for α and for the corresponding equation obtained by normalizing (3) on x rather than on y. We report also fourth-order LM-tests - which are approximately distributed as Chisquare - to assess the null that residuals in (4) are not serially correlated.

In the cointegrating equation we regress the smoothed trend of the log of real GNP (y) on the smoothed trend of the log of major expenditure components (consumption, fixed investment, final government expenditure, exports and imports of goods and services). The growth variables are obtained by applying HP filter to the observed expenditure and GNP/GDP data.

COINTEGRATION TESTS (ADF) FOR GROWTH COMPONENTS

Cointegration between real GNP/GDP and X_i normalized on:

USA	GNP	Chisq(4)	X_i	Chisq(4)
Consumption	-1.55	1.01	-1.64	1.03
Investment	-2.10	2.19	-2.15	2.25
Govt. expend.	-3.52	3.88	-3.95	4.36
Imports	-2.89	2.34	-2.68	2.43
Exports	-3.48	13.10	-5.93	13.54
Canada				
Consumption	-2.99	5.49	-2.88	5.43
Investment	-0.81	0.71	-0.59	1.15
Govt. expend.	-0.74	2.12	-1.03	2.00
Imports	0.05	2.86	0.10	2.80
Exports	-2.63	0.63	-2.82	0.39
Japan				
Consumption	-3.00	4.67	-2.97	4.70
Investment	-2.46	11.90	-2.35	10.71
Govt. expend.	0.01	5.91	-0.13	5.77
Imports	-2.01	8.16	-1.92	6.74
Exports	-2.28	7.61	-2.28	7.81
Germany				
Consumption	-2.85	7.10	-2.92	6.96
Investment	-2.64	4.29	-2.38	4.85
Govt. Expend.	-1.61	9.64	-1.63	9.74
Imports	-2.32	4.42	-2.36	4.30
Exports	-2.06	5.94	-2.09	5.94
France (70Q1-89Q3)				
Consumption	-1.93	5.83	-1.94	5.82
Investment	-1.22	2.30	0.05	1.85
Govt. Expend.	-0.18	4.65	-0.36	4.49
Imports	-0.65	4.75	-0.30	4.49
Exports	-1.42	12.71	-1.49	12.56
UK				
Consumption	-1.03	8.81	-0.90	8.65
Investment	-3.73	5.07	-2.40	8.35
Govt. Expend.	-3.04	2.57	-2.89	2.88
Imports	-0.46	5.70	-0.32	5.63
Exports	-0.74	8.25	-1.08	7.70
Italy (70Q1- 89Q3)				
Consumption	-0.37	3.16	-0.33	3.18
Investment	-1.34	18.11	-0.81	17.69
Govt. Exp.	-2.06	11.03	-2.32	12.50
Imports	-0.23	5.72	-0.13	5.71
Exports	-1.74	4.17	-1.97	4.29