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Methodological and empirical issues in real business cycle theory

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In this paper, we argue that the major impact of the RBC literature has been to propose a new methodology for macroeconomics. This methodology is distinguished first by the importance it attributes to the empirical description of the phenomena to be explained and, second, by the use of this description in conjunction with 'quantitative theorizing', i.e., the construction of computable general equilibrium models whose characteristic statistics match those of the data. In accordance with this approach, we first report on the current state of knowledge concerning business cycle regularities and conclude that additional empirical effort is called for in order to arrive at the appropriate basis for theorizing. We then examine the performance of existing models and evaluate the case for integrating monetary factors and demand shocks into them. Lastly we review the recent efforts to explain the employment variability puzzle, and argue that the search for a solution naturally leads to the incorporation of significant non-Walrasian features into the RBC framework.

1. Introduction

The decade of the 1980s has witnessed a rapidly expanding literature known as Real Business Cycle (RBC) theory. This perspective, initiated by Kydland and Prescott (1982) and Long and Plosser (1983), has provoked considerable discussion within the macroeconomics profession. RBC theory

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has recently been the focus of several surveys [Danthine (1989), McCallum (1989), Mankiw (1989) and Plosser (1989a, b)] whose main thrusts we will not attempt to replicate here. Rather, we shall (1) focus on the methodological import of this body of work (section 1); (2) summarize the current state of empirical knowledge about business cycle phenomena, the outcome of a process of collecting stylized facts largely stimulated by the methodological requirements of the RBC approach itself (section 2); and (3) discuss the significance to be attributed to the most frequent criticisms of RBC models and assess what influences these criticisms may have on future research (section 3).

In our view the RBC label is unfortunate as the major contribution of this body of research is not a denial of any substantive role for money in explaining business cycle phenomena, but rather the establishment of a new research methodology for the study of the business cycle. The first component of this proposed methodology is an 'empirical reassessment' which calls for a more systematic and complete statistical characterization of the economic fluctuations to be explained. The second component is the recourse to what has been called 'quantitative theory', i.e., the building of small, micro-based, computable, general equilibrium dynamic models which can be evaluated not only qualitatively but also quantitatively in terms of their ability to replicate the basic business cycle stylized facts.

None of these components, taken separately, is particularly new. Their close coordination in the advancement of an important branch of economics is, however, distinctive and, in our view, likely to have important consequences for the whole of macroeconomic theory on at least three levels. First, it will stimulate a move towards a more inductive approach to macroeconomic research, with the accent being placed on a more systematic qualitative and quantitative description of the facts to be explained. Second, we believe the practice of developing 'quantitative theory' will spread to other applications, mitigating the importance attributed to purely qualitative results. Thirdly, added research discipline will come from the view that a successful theoretical model must be one which not only explains the stylized facts at its focus but which is also broadly consistent with other accepted aspects of reality. Partial models which are calibrated successfully to explain one fact (or set of facts), but which do so while contradicting other accepted empirical findings, will not be accorded much value.

With such emphasis on the stylized facts and despite so much having been written on the subject of business cycles over the years, the RBC program has forced theorists to recognize how incomplete our knowledge of basic business cycle phenomena actually was. Remedying this shortcoming is the first challenge of RBC theory and its first contribution. In section 2, we provide a progress report on the efforts made to obtain a complete, precise description of business cycle phenomena.

The second step in the RBC approach is the construction of equilibrium models capable of replicating as many as possible of the stylized facts thus uncovered. This additional requirement – that a successful model should not only replicate the data qualitatively but also quantitatively – may appear quite natural. In practice, however, it tends to reduce the relative significance of the qualitative approach. Why should a model which predicts a large positive value for a variable whose empirical magnitude is 0.1 be preferred to a model which quantitatively predicts a value of -0.05 for that same variable? It further introduces important issues of calibration (what are the values to be chosen for model parameters?), and testing (when can a model's predictions be said to be successful and when can they be said to have been falsified?). The former of these two considerations, especially, forces a greater consistency in macroeconomic theory vis-à-vis micro studies.

A natural strategy for the execution of such an ambitious program is first to examine well known existing dynamic models to determine how well they perform. Such logic fully justifies the attention given the stochastic growth paradigm – a Walrasian model without money – by RBC authors to date. Its attractiveness as a starting point has been further enhanced by demonstrations that its optimal allocations can also be viewed as competitive equilibria [cf. Prescott and Mehra (1980) and Brock (1979)].

These initial attempts to construct a theory have, however, generated substantial misunderstanding and dogmatic posturing while revealing how we, macroeconomists, have been accustomed to think. Indeed, the idea of even proposing and 'testing', in the above sense, a purely Walrasian model of the cycle has generated heated objections, sometimes aggravated by the misguided claim that these initial attempts conclusively demonstrated that business cycle phenomena were nothing more than the optimal reaction of rational agents to exogenous productivity shocks. In reality, the RBC methodology is by nature ideologically neutral in the sense that it prefers the model or set of models that is (are) best able to replicate the stylized facts independent of the hypotheses underlying it (them). The best RBC model may thus ultimately be a demand-driven money model with substantial non-Walrasian features. Such a convergence should occur, however, not on the basis of prior views but as the outcome of a process of building increasingly richer models and confronting them with an increasingly richer set of stylized facts.

As this paper will make clear, it is largely premature to claim victory of one model paradigm over another given the modest set of facts which current models are able to replicate. Even at this stage, however, a clear achievement of the RBC literature has been to free us to reconsider what we know about the business cycle. In the next section we illustrate the set of questions and results this reconsideration has provided. This is followed, in section 3 by a review of various proposed model paradigms while section 4

Table 1

Statistical properties; U.S. economy.[a,b]

Series	(a)	(b)	(c)
Output	1.76	1.00	1.00
Consumption	1.29	0.73	0.85
Investment	8.60	4.89	0.92
Capital stock	0.63	0.36	0.04
Hours	1.66	0.94	0.76
Productivity (average)	1.18	0.67	0.42

[a]*Source*: Hansen (1985), Table 1; the above results are derived from quarterly data which have been detrended using the Hodrick and Prescott (1980) filter methodology.

[b](a) standard deviation (s.d.) in %, (b) s.d. relative to output, (c) correlation with output.

provides an overall assessment of the progress of RBC theory to date and concludes the paper.

2. The business cycle facts

2.1. The standard description

Table 1 is the benchmark summary of basic business cycle stylized facts for the U.S. economy that have been presented in most RBC studies to date.

The corresponding qualitative equivalent is well known and can be summarized as follows: Investment is more variable than output while consumption is less variable and capital stock much less so. The variability of hours is about the same as that of output and more pronounced than the variability of (averaged across all workers) productivity.[1] All of these variables are procyclical except the stock of capital whose contemporaneous correlation with output is nearly zero.

One reaction to this description is to notice how modest it is. Surely there are other substantive business cycle regularities that have been uncovered and which could be included in the list of facts to be explained. This is indeed the case, and one of the primary objectives of this section will be to assemble the less well known regularities that have been identified by various authors. A second reaction is to notice that it is limited to the U.S. This latter fact is especially unsatisfactory. It is thus important, as we attempt to enlarge the list of stylized facts, to segregate those international regularities for which there is likely to exist a 'unified explanation (...) grounded in the *general laws* governing market economies' [Lucas (1977)] from those that

[1]Many countries do not produce statistics for hours. We thus report facts on employment below. For the U.S., employment varies somewhat more than hours, but the relative variability of employment and productivity is the same as for hours and productivity.

probably cannot be explained without reference to national institutions and policy practices. In the following sections, we survey what is known in this regard.

For our description of these 'stylized facts', we have systematically followed the current practice of detrending the data with the Hodrick–Prescott (1980) filter. The merits of this filter are numerous: It is simple to use and highly operational; the definition of trend it provides is intutive; it is able to render stationary, series that are integrated up to the fourth order [King and Rebelo (1989a)], and no dominating alternative procedure has yet been proposed. Being statistical in nature, it represents a particular way of viewing the data which can be very productive if accepted and used by most researchers. Given that it leads us to contemplate the data from a specific angle which may distort some important facts, however, we share King and Rebelo's (1989a) view that other perspectives should be adopted as well so as to achieve a more complete description of the business cycle facts.

2.2. GNP and its components

In contrast to table 1, table 2 and the tables following adopt an international perspective on business cycle regularities. Further details as to the sample periods for each of our 156 variables (table 9) are also provided. We first comment upon the set of facts directly comparable to the summary observations described in table 1 (part A of tables 2, 3, and 4).

The general message of table 2 is to confirm the facts obtained for the U.S. although the conformity is more robust for investment, which is uniformly more variable than output by a factor of two to three than for consumption whose variability, quite surprisingly, exceeds that of output in four of ten cases. Government spending is typically more variable than output with Switzerland being the sole exception. At this level, one can thus speak of international regularities [as Danthine and Girardin (1989) have observed with a more limited sample] although the precise numbers retained in table 2A help put this statement in perspective. Note, in particular, that on the basis of this data, the (relative to output) standard deviation of consumption is lowest for the U.S. Consumption smoothing is apparently less prevalent elsewhere.

In tables 3A and 4A, a similar comparison of cross correlations with output and first order autocorrelations is performed. Note, in particular, that consumption and investment are highly procyclical everywhere with the U.S. being rather at one extreme here as well. The behavior of government spending differs substantially from country to country, both with regard to correlation with output and with regard to its own behavior through time.

In addition to the facts recorded in tables 2–4, table 1 shows that the stock of capital in the U.S. varies hardly at all (relative to output) and is almost

Table 2[a,b]

Standard deviations of detrended variables.

	Part A				Part B			Part C									
Country	*GNP* %	*CONS*	*INV*	*GOV*	*EXP*	*IMP*	*NX*	*DEFL* (s.d. relative to s.d. of output)	*PC*	*M1*	*M2*	*RST*	*RLT*	*MIR*	*VM1*	*M2R*	*VM2*
1. Australia	1.75	1.36	2.47	2.11	3.48	4.39	0.78	1.54	0.91	2.07	1.93	1.14	0.43	2.51	2.06	2.13	1.98
2. Austria	1.42	1.65	3.48	2.13	3.82	3.64	1.35	0.90	0.83	2.13	1.00	0.77	0.98	2.17	2.37	1.30	1.61
3. Canada	1.41	0.94	3.02	1.37	3.31	4.13	0.55	1.19	0.93	3.97	4.68	1.10	0.61	4.36	4.24	4.35	4.43
4. France	0.89	1.58	2.28	2.78	5.03	6.98	0.94	1.37	1.59	3.17	8.09	1.83	1.20	3.11	3.15	8.47	8.26
5. Germany	1.67	0.72	3.28	1.26	2.41	2.69	0.51	0.58	0.65	1.42	1.21	1.01	0.49	1.53	1.56	1.48	1.67
6. Italy	1.88	1.82	2.90	1.95	3.27	4.51	0.78	1.50	1.19	3.76	2.65	1.16	0.62	3.79	3.62	2.88	3.13
7. Japan	1.66	0.73	2.80	3.76	4.21	7.03	0.60	1.19	1.29	2.00	0.93	1.04	0.67	2.35	2.35	1.72	1.77
8. South Africa	1.64	2.06	4.13	3.47	4.25	6.39	2.04	1.92	0.77	3.99	4.61	1.30	0.48	3.88	3.83	4.51	4.60
9. Switzerland	2.29	0.74	2.81	0.80	1.90	3.19	0.66	0.85	0.82	2.19	2.03	0.87	0.28	2.45	2.52	2.41	2.07
10. U.K.	1.53	1.14	2.51	1.71	3.13	4.44	0.70	1.45	1.36	2.06	4.82	1.04	0.59	2.68	2.25	5.22	5.20
11. U.S.A.	1.73	0.71	3.01	1.18	3.94	2.99	0.25	0.52	0.83	0.93	1.55	0.73	0.47	1.25	1.17	1.95	1.71
12. EC 12	1.12	0.87	2.23	0.47	2.10	2.91	0.51	0.89	1.35	1.14	0.82	–	–	1.72	1.38	1.48	0.99

[a]*Sources*: Quarterly data, International Financial Statistics (IMF) for all countries; Datastream for the EC. Series are seasonally adjusted and detrended with the Hodrick–Prescott filter. See table 9 for details on the sample period.

[b]In tables 2–8, all standard deviations are computed using the longest available sample period while cross correlations are computed with respect to the shorter of the two sample periods. See table 9 for the sample periods.

Table 3

Cross-correlations with output (all variables detrended).

	Part A			Part B			Part C									
Country	*CONS*	*INV*	*GOV*	*EXP*	*IMP*	*NX*	*DEFL*	*PC*	*M1*	*M2*	*RST*	*RLT*	*M1R*	*VM1*	*M2R*	*MV2*
1. Australia	0.66	0.68	0.38	0.52	0.55	−0.14	−0.49	−0.43	0.37	0.02	0.06	−0.09	0.61	0.26	0.38	−0.10
2. Austria	0.57	0.33	0.04	0.06	0.56	0.60	−0.10	−0.22	−0.02	−0.03	0.32	−0.34	0.02	−0.40	0.04	−0.59
3. Canada	0.67	0.60	−0.22	0.69	0.78	−0.32	−0.36	−0.45	0.15	−0.06	0.33	0.08	0.23	0.00	0.04	−0.19
4. France	0.46	0.53	−0.10	0.31	0.36	−0.23	−0.52	−0.44	−0.10	0.19	0.21	0.01	0.12	−0.19	0.26	0.15
5. Germany	0.64	0.83	−0.01	0.22	0.43	−0.27	−0.14	−0.41	0.25	0.10	0.36	0.15	0.29	−0.36	0.14	−0.48
6. Italy	0.41	0.80	0.36	0.22	0.57	−0.45	−0.33	−0.39	0.17	−0.27	0.22	−0.26	0.30	0.04	−0.08	−0.39
7. Japan	0.49	0.81	−0.19	−0.10	0.16	−0.27	−0.27	−0.44	0.09	0.09	0.06	−0.20	0.21	−0.21	0.24	−0.34
8. South Africa	0.31	0.37	0.18	0.02	0.70	−0.56	0.09	0.18	0.21	0.05	−0.03	0.15	0.18	−0.08	0.01	−0.21
9. Switzerland	0.78	0.78	0.36	0.65	0.81	−0.67	−0.25	−0.19	0.05	0.52	0.38	0.36	0.13	−0.27	0.53	0.13
10. U.K.	0.69	0.70	0.00	0.43	0.46	−0.21	−0.58	−0.58	0.35	−0.06	0.08	−0.22	0.58	0.25	0.12	−0.07
11. U.S.A.	0.85	0.90	0.09	0.18	0.56	−0.30	−0.59	−0.55	0.30	0.40	0.33	0.01	0.47	−0.35	0.48	−0.04
12. EC 12	0.84	0.89	0.11	0.79	0.92	−0.58	−0.76	−0.69	0.31	0.51	–	–	0.59	0.01	0.74	0.10

Table 4

First-order autocorrelations.

	Part A				Part B			Part C									
Country	*GNP*	*CONS*	*INV*	*GOV*	*EXP*	*IMP*	*NX*	*DEFL*	*PC*	*M1*	*M2*	*RST*	*RLT*	*MIR*	*VM1*	*M2R*	*VM2*
1. Australia	0.51	0.26	0.65	0.47	0.59	0.74	0.76	0.48	0.89	0.79	0.86	0.75	0.78	0.62	0.62	0.58	0.68
2. Austria	0.43	0.07	0.46	−0.21	0.29	0.60	0.11	0.34	0.83	0.76	0.72	0.80	0.61	0.62	0.59	0.53	0.45
3. Canada	0.78	0.74	0.81	0.60	0.76	0.82	0.61	0.94	0.93	0.74	0.71	0.78	0.78	0.78	0.75	0.68	0.69
4. France	0.79	0.69	0.77	0.71	0.78	0.78	0.73	0.88	0.94	0.65	0.63	0.86	0.90	0.60	0.57	0.66	0.65
5. Germany	0.67	0.47	0.70	0.45	0.67	0.75	0.67	0.74	0.87	0.79	0.24	0.83	0.88	0.82	0.76	0.46	0.48
6. Italy	0.66	0.59	0.75	0.26	0.39	0.82	0.65	0.62	0.93	0.60	0.63	0.78	0.88	0.57	0.52	0.54	0.58
7. Japan	0.75	0.54	0.87	0.00	0.84	0.89	0.81	0.88	0.87	0.56	0.55	0.80	0.70	0.65	0.62	0.79	0.72
8. South Africa	0.67	0.33	0.68	0.43	0.59	0.72	0.76	0.33	0.84	0.75	0.79	0.92	0.80	0.73	0.71	0.70	0.71
9. Switzerland	0.74	0.57	0.82	0.14	0.76	0.83	0.70	0.87	0.93	0.79	0.61	0.77	0.91	0.82	0.79	0.69	0.60
10. U.K.	0.58	0.64	0.68	0.46	0.61	0.78	0.66	0.88	0.87	0.58	0.90	0.78	0.78	0.69	0.54	0.90	0.90
11. U.S.A.	0.84	0.77	0.88	0.82	0.78	0.68	0.78	0.91	0.94	0.82	0.89	0.77	0.81	0.88	0.81	0.91	0.87
12. EC 12	0.78	0.74	0.82	0.57	0.68	0.81	0.76	0.86	0.89	0.87	0.89	–	–	0.87	0.76	0.87	0.70

acyclical. A closer look would reveal that the U.S. capital stock lags the cycle by at least a year. Data availability restricts the international comparisons we are able to make in this regard.

There are a number of other stylized non-price facts which have been cited for the U.S. economy for which the corresponding international evidence is not yet available. We list the more prominent of these in the remainder of this section.

Consider first inventories. For the U.S. economy, inventory changes are, on average, half the size of quarterly changes in GNP though inventory investment itself averages only 0.6% of GNP [Christiano (1988)]. Inventories move procyclically [Kydland and Prescott (1982) report a correlation with output of 0.51] and peak, prior to a cyclical downturn, later than GNP [Prescott et al. (1983)]. Wilkinson (1989a, b) presents an international comparison of inventory behavior for a selected group of countries along two dimensions: Inventory investment as a percent of GNP and the contribution of inventories to output instability (in the sense of measuring the degree to which production is more variable than sales). With respect to the first measure he reports that inventory investment ranges from 0.7 to 2% (for Japan, surprisingly) of GNP. With respect to the second, production ranges from 12 to 56% more variable than sales in the sample he considers. Thus there would appear to be substantial variance in inventory behavior across countries.

Greenwood and Hercowitz (1991) study the relative accumulation of household capital (consumer durables and residences) versus business capital. For the period 1954–1988 they report that household capital in the U.S. exceeds business non-residential capital on average by a factor of 13%. They also report that investment in household capital is highly procyclical and tends to lead movements in business investment. That these statistics should be of interest comes from the fact that authors have estimated (again for the U.S. economy) the value of home production to range between 20% and 50% of GNP. As we shall see, provocative new theories of the business cycle build on this observation.

Although a typical RBC model features one (composite) good, the reality is that modern economies are all multisectored. For the U.S. economy, it is an accepted fact that all sectors are procyclical [see Long and Plosser (1983) and Benhabib et al. (1991)].

2.3. *Monetary variables and prices*

Among the principal regularities of the business cycle, Lucas (1977) cites the following three: 'Prices are procyclical; short-term interest rates are procyclical, long-term rates slightly so. Monetary aggregates and velocity measures are procyclical'.

As evidence assembled in table 5 clearly confirms, however, the procyclicity of prices, which is at the root of the monetary misperceptions business cycle class of models, is largely contradicted by the data for the post-war period. With South Africa the only exception, the GDP deflator's contemporaneous correlation with output is always negative. This result remains unchanged for one period leads or lags. The picture is different, however, with longer leads: There is evidence here of a positive price output correlation most notably for Germany, Austria, Canada, Italy, and Switzerland. Focusing on the case of Switzerland, Danthine and Girardin (1989) show that the correlation between the price deflator and GNP is positive after *linear* detrending. While the latter is probably inappropriate, this observation raises a potential problem of interpretation. If the countercyclicality of prices were specific to Hodrick–Prescott (HP) filtered data, it would be difficult to advance, without qualification, the claim that price procyclicality is a myth [Kydland and Prescott (1990)]. Fortunately, for U.S. data at least, the result obtained using the HP filter appears to be confirmed (for the postwar period) when the data is examined from a variety of angles [see Cooley and Ohanian (1991)]. Wolf (1991), on the other hand, concludes that procyclicity is a recent (post 1973) phenomenon, at least for the U.S.

The remarkable aspect of table 2C on the other hand, is the general absence of strong regularities. With regard to all countries, we can only assert that long term rates are less variable than short term rates. For all other series, the relative (to output) standard deviations vary substantially across countries and the variability of the real monetary measures bear no consistent relationship to their nominal cousins.

The same general impression comes across in table 3C. Although short rates are generally positively correlated with output (South Africa being the exception) no systematic pattern is observed vis-à-vis long rates. For the postwar period, at least, it does not appear that Lucas's (1977) second regularity is robust internationally. Velocity measures are also generally negatively correlated with output again with certain significant exceptions, e.g., France and Switzerland for M2. As to the correlation with output of both monetary measures, these are generally positive, with two exceptions in the case of M1, four in the case of M2. This absence of robust regularities is not surprising, however, given the wide range of monetary policies that have been implemented over the years. What may be more striking is to realize that the wide range of monetary policies evidenced in tables 2, 3 and 5 is consistent with the same general pattern in the co-movements and relative variability of the major real aggregates. This provides support for the claim that the absence of monetary features in this class of models is a reasonable first approximation, acceptable at this stage of business cycle theory. The international regularities reported here also suggest that U.S. observations may not necessarily be a useful guide to international regularities.

Table 5

GDP deflator.

	Standard deviation relative to output	Correlation with output at different lags										
		Y_{T-5}	Y_{T-4}	Y_{T-3}	Y_{T-2}	Y_{T-1}	Y_T	Y_{T+1}	Y_{T+2}	Y_{T+3}	Y_{T+4}	Y_{T+5}
1. Australia	1.54	0.17	0.24	0.36	0.07	−0.09	−0.49	−0.24	−0.21	−0.07	−0.01	−0.02
2. Austria	0.90	−0.30	−0.19	−0.20	−0.18	−0.24	−0.10	−0.01	0.06	0.07	0.20	0.23
3. Canada	1.19	−0.49	−0.53	−0.53	−0.48	−0.42	−0.36	−0.21	−0.07	0.04	0.13	0.21
4. France	1.37	−0.29	−0.40	−0.51	−0.58	−0.56	−0.52	−0.46	−0.36	−0.27	−0.17	−0.08
5. Germany	0.58	−0.32	−0.35	−0.35	−0.29	−0.24	−0.14	0.07	0.23	0.34	0.37	0.46
6. Italy	1.50	−0.35	−0.44	−0.51	−0.55	−0.46	−0.33	−0.15	−0.01	0.07	0.20	0.24
7. Japan	1.19	−0.35	−0.40	−0.41	−0.39	−0.33	−0.27	−0.22	−0.12	−0.06	0.04	0.06
8. South Africa	1.92	0.34	0.31	0.34	0.30	0.27	0.09	0.11	0.06	0.09	−0.03	−0.03
9. Switzerland	0.85	−0.44	−0.42	−0.41	−0.43	−0.40	−0.25	−0.09	0.07	0.26	0.45	0.56
10. U.K.	1.45	−0.08	−0.23	−0.35	−0.47	−0.54	−0.58	−0.49	−0.39	−0.21	−0.07	0.11
11. U.S.A.	0.52	−0.46	−0.56	−0.64	−0.68	−0.66	−0.59	−0.48	−0.35	−0.22	−0.09	0.04
12. EC 12	0.89	−0.13	−0.34	−0.55	−0.70	−0.75	−0.76	−0.64	−0.48	−0.29	−0.11	0.06

2.4. Labour market regularities

From table 1 we know that employment (hours) is strongly procyclical and almost as variable as output while productivity varies less and is less highly correlated with output. These facts have received much attention in the literature because, contrary to those reported in section 2.2, they are not naturally replicated in standard models (see section 3.4) – hence the label 'employment variability puzzle' suggested by Prescott (1986). Christiano and Eichenbaum (1990) have however argued that the near zero correlation of employment and productivity and employment and real wages, first identified by Dunlop (1938) and Tarshis (1939), constitutes an equally significant puzzle.

The relevant international data are assembled in table 6, and a number of striking features merit comment. First, the standard deviation of employment relative to output is quite variable across countries, ranging from 0.50 (Italy) to 1.34 (South Africa); a similar broad band of values is observed for the standard deviations of productivity and the real wage relative to output. Note that in both these instances, the observations for the U.S. fall at the lower end of the spectrum. The ratios of the standard deviation of employment to the standard deviation of productivity range between 0.52 (Italy) and 1.4 (U.S.). Though generally positive, the various correlations with output lack any consistent pattern. The real wage, for example, can be procyclical (five countries), acyclical (four countries) or countercyclical (two countries).

It is also noteworthy that the correlations between employment and output is never higher than 0.83, with the U.S. again assuming this extreme value. Finally, and most interestingly, productivity and employment are strongly negatively correlated for all countries except the U.S. and Austria, where they are close to zero. All in all, it appears that *labor market behavior is substantially different across countries*, most likely reflecting distinct cultural and institutional arrangements. It is unlikely that any single model formulation alone will be able to account for this wide range of phenomena.

Additional information is available for the U.S. economy which demands confirmation on an international basis. The total hours series, in particular, has been decomposed into employment fluctuations and variations in hours per worker. For the U.S. approximately 2/3 of the variation in total hours appears to be due to movements in and out of the labor force and 1/3 to adjustments in hours worked of the labor force participants [Cho and Cooley (1989)]. It further appears that the length of the average workweek peaks before GNP peaks, and that employment lags the cycle, while hours per worker is nearly contemporaneous with only a slight lead [Kydland and Prescott (1990)].

Even more important, it is clear that the standard measure of labor input

Table 6

Labor market variables.

	Sd relative to sd of output				Correlation with output				First-order autocorrelation				Corr	Corr
	W	*N*	*WR*	*PROD*	*W*	*N*	*WR*	*PROD*	*W*	*N*	*WR*	*PROD*	(*WR*, *N*)	(*PROD*, *N*)
1. Australia	1.21	1.21	1.68	1.31	−0.23	0.30	0.26	0.48	0.79	0.83	0.46	0.61	0.18	−0.69
2. Austria	1.35	0.59	1.23	0.84	−0.11	0.54	−0.05	0.81	0.56	0.67	0.15	0.34	0.02	−0.06
3. Canada	1.20	0.88	1.15	0.76	−0.50	0.68	−0.16	0.53	0.79	0.89	0.72	0.68	−0.57	−0.26
4. France	2.11	0.72	1.37	1.04	−0.29	0.30	0.07	0.75	0.85	0.94	0.62	0.78	0.22	−0.40
5. Germany	1.13	1.18	0.72	0.92	−0.29	0.65	−0.34	0.25	0.81	0.94	0.63	0.63	0.29	−0.57
6. Italy	1.77	0.50	1.33	0.96	−0.32	0.34	−0.04	0.87	0.85	0.78	0.42	0.61	0.03	−0.17
7. Japan	1.08	0.64	1.77	0.86	0.59	0.53	0.54	0.77	0.74	0.91	0.84	0.64	0.27	−0.13
8. South Africa	–	1.34	–	1.18	–	0.51	–	0.25	–	0.92	–	0.72	–	−0.70
9. Switzerland	0.72	0.92	0.52	0.70	0.01	0.73	0.38	0.47	0.87	0.94	0.57	0.50	0.40	−0.26
10. U.K.	1.49	0.98	1.02	1.03	−0.37	0.45	0.38	0.54	0.84	0.95	0.63	0.61	0.12	−0.51
11. U.S.A.	0.42	0.80	0.37	0.56	−0.27	0.83	0.53	0.60	0.73	0.90	0.66	0.74	0.36	0.05
12. EC 12	1.19	0.55	0.88	0.89	−0.56	0.47	0.02	0.84	0.50	0.62	0.18	0.60	0.21	−0.08

is not quality adjusted: Hours of work are given equal weight irrespective of the relative contribution of the particular worker to aggregate output. Kydland and Prescott (1988) detail the importance of this distinction by emphasizing that the cyclical variability of highly skilled workers is much smaller than that of less skilled workers. Weighing people by their relative human capital, they conclude that the quality adjusted labor input for their sample (5,000 people of all major demographic groups) in the chosen period (1969–82) varies only about two thirds as much as does their aggregate hours.

2.5. *International business cycle characteristics*

Thus far the reported stylized facts concern only the home sectors of different economies. Thinking now in terms of open economies in relation to one another, we report a set of facts which are a natural extension of the domain of business cycle models. For recent attempts in that direction see, e.g. Backus and Kehoe (1989) and Backus et al. (1989a, b).

We first note (tables 2B and 3B) that imports and exports are more variable than output and generally procyclical (more strongly so for imports). Net exports are uniformly negatively correlated with output. Japan is an exception with a negative contemporaneous correlation of exports. Japanese exports also lag the cycle by four or five quarters.[2] A number of other significant regularities are noteworthy:

(1) First is the observation (table 7) that output fluctuations are, with few exceptions positively correlated across countries, in some cases (e.g., France and Germany) quite strongly so. For most countries, output is strongly positively correlated with U.S. output. Canadian output correlation is highest in this regard. Viewed from another perspective, the fact that output correlations are far from perfect suggests the possibility for international diversification. This is illustrated by the distinct behavior of the aggregate we report as the EC (12).
(2) Backus and Kehoe (1989) and others report that cross country consumption correlations are also positively correlated though less so than output. The opposite would be expected from straightforward linkages of one-good economies as international risk sharing would then lead consumption to be perfectly correlated across countries. This puzzle has stimulated several developments: see our concluding comments.
(3) Within a country, savings and investment are frequently very highly positively correlated, again with a few notable exceptions. This fact has

[2]U.S. exports appear to lag the cycle by about a year.

Table 7

Postwar international output correlations.

	Austr.	Aus.	Canada	France	Germany	Italy	Japan	S.A.	Switz.	U.K.	U.S.A	EC
1. Australia	1.00	0.18	0.36	0.22	0.39	0.11	0.25	0.27	0.33	0.16	0.24	0.11
2. Austria		1.00	0.29	0.46	0.58	0.34	0.24	−0.07	0.64	0.32	0.31	0.00
3. Canada			1.00	0.20	0.41	0.27	0.18	0.06	0.28	0.33	0.76	0.15
4. France				1.00	0.61	0.48	0.41	−0.03	0.56	0.52	0.38	0.17
5. Germany					1.00	0.24	0.48	−0.04	0.53	0.44	0.43	0.24
6. Italy						1.00	0.26	0.14	0.62	0.10	0.33	−0.16
7. Japan							1.00	−0.15	0.35	0.36	0.27	0.36
8. South Africa								1.00	0.22	−0.21	−0.17	−0.51
9. Switzerland									1.00	0.21	0.29	−0.21
10. U.K.										1.00	0.45	0.33
11. U.S.A.											1.00	0.44
12. EC 12												1.00

usually been interpreted as evidence of surprisingly low international mobility of capital [see Feldstein and Horioka (1980) and Feldstein and Bachetta (1989) and the references cited therein]. Such an interpretation is disputed by Baxter and Crucini (1989) who use RBC methodology to shed new light on the observed investment/saving correlations.

2.6. *Other stylized facts*

Being organized extensions of the stochastic growth paradigm, RBC models will typically have predictive power along dimensions other than those associated with the notion of the business cycle. It is fully within the spirit of the RBC methodology to check the congruence of these latter predictions with the stylized facts.

The set of financial regularities is particularly relevant. Current RBC models have no explicit financial sector. Nevertheless, implicit prices and real return on financial assets can be computed. Here we emphasize a select number of predictions on which the model appears to be at odds with the data. The following points are most significant:

(i) The equity premium puzzle of Mehra and Prescott (1985). Over the 1926–1977 period, stocks have paid an average geometric return of 8%, a fact which the standard growth model is unable to replicate, unless implausibly high rates of risk aversion are assumed.
(ii) The risk free rate puzzle [Weil (1988)]. On the other extreme, the geometric real return on T-bills has been too low [0% for the period 1926–1977 with a standard deviation of 4.6% [Ibbotson and Sinquefeld (1976)]] to be explainable by standard models.

The results obtained by Weil (1988) have shown that the equity premium puzzle and the risk free rate puzzle are aspects of the same problem in that for the standard setup increases in the risk premium can be bought only at the cost of increases in the risk free rate.
(iii) The relationship of growth and business cycle theories is another natural focus of attention. We note only that growth observations have been interpreted as requiring either important modifications in the assumed methodology [increasing returns to scale, Romer (1986)], or a technology for accumulating a capital good which does not depend on fixed factors [Lucas (1988)], or noncompetitive behavior of firms [Romer (1986, 1989)]. Furthermore, the time path of growth rates seems inconsistent with the functioning of the neoclassical model [King and Rebelo (1989b)]. All of these adaptations represent significant departures from the neoclassical paradigm. It is not yet clear that the ability of the current models to explain the business cycle stylized facts will be robust to these changes.

2.7. *The empirical contribution of RBC theory: An assessment*

In the preceding subsections, we have assembled a set of stylized facts with the purpose of characterizing business cycle phenomena. The same economic reality could obviously be described using other data perspectives. RBC theorists have found the above format a useful springboard for theorizing, but it is not an exclusive one: Lead and lagged correlations have traditionally been, and remain, an integral part of a complete description and have been excluded here, with few exceptions, only because of space limitations. Other aspects of business cycle phenomena can be approached using VAR analysis or by characterizing impulse response functions.

This notwithstanding, there remains a number of unresolved issues which we feel have attracted an insufficient amount of attention. Let us mention two of these topics. First, with so many international differences in business cycle facts, isn't the search for a unifying explanation of all business cycle phenomena somewhat misplaced? In other words, what are the distinguishing features of other economies and how should we organize our thinking about them in view of integrating these features into our model building? Second, to what extent do the benchmark stylized facts used in the literature depend upon the selection of time periods or variations in policy regimes? In our view, these are two key questions that should not be ignored much longer if the promises of the RBC research program are to be fulfilled.

3. Modeling issues

3.1. *The strategy*

Equipped with a broad, yet still incomplete and sometimes tentative description of the business cycle facts, one can turn to theoretical models and test their ability to explain the data; that is, their ability to replicate the qualitative and quantitative features of the business cycle. The process is an unending one, consisting of first testing simple and well understood models, of enriching them in order to progressively extend their realm of prediction and of then altering them as their implications are falsified in confrontation with the data. While the premier model of dynamic economics, the stochastic growth model, has been to date the natural foundation of the theory, in this view, the direction the theory will take in the future should be exclusively determined by the ability of its successors to pass the increasingly severe tests to which they will be subject. The objection that one cannot seriously think of explaining business fluctuations with a competitive Walrasian model where the equilibrium is Pareto optimal should be dismissed on the grounds that models should not be chosen on the basis of researchers' ideological priors but strictly on the basis of their ability to explain the facts (although

the choice of model may be interpreted as a forecast on the outcome of the testing process).

On the other hand, the claim that business cycle fluctuations are fully explained as the optimal reaction of private agents to exogenous shocks (based on the unexpectedly favorable performance of the stochastic growth paradigm and its derivatives) is clearly premature, given the short list of facts that has initially served to 'define' the business cycle (and that existing models have proved able to replicate satisfactorily). Understandably, the future directions researchers will pursue in their attempt to resolve the succession of 'puzzles', which progressive data analysis must inevitably identify, will depend upon their priors as to the mechanisms most likely to be successful, priors which are inescapably tainted ideologically. Such a process could well lead at some stage to observationally equivalent models; that is, models based on different working principles which replicate the stylized facts equally well. (The 'tie' will be broken with the advent of new stylized facts!). Ultimately, there is no reason to believe that the process will be ideologically biased and the best model of the business cycle may prove to be one with characteristics radically different from those that have pioneered this literature.

One may also object that the computability requirement in itself induces a bias in favor of Walrasian models with optimality properties. While this has been the case in the initial development stage of this body of work, the advantage is rapidly disappearing: Researchers are becoming increasingly experienced in the computation of non-optimal general equilibrium models as they perceive the need to push the theory further in that direction [see, e.g., King et al. (1988a, b)].

With these principles in mind, we can now assess several lines of development in this literature in conjunction with the most frequent criticisms that have been levied against it. We successively examine the money issue (are business cycles 'real'?), the question of the source of shocks (demand vs productivity shocks) and review the modelling of the labor market in RBC models as a good illustration of the process of development of the literature.

3.2. What about money?

Most RBC models to date are models without money. They thus stand in sharp contrast to the seminal equilibrium business cycle model of Lucas (1972, 1975) where money, together with imperfect price information, was holding center stage. It remains to be seen to what extent Lucas' effort was misguided as the result of his perception that prices are procyclical.

Kydland and Prescott are reported as having originally intended to analyze business cycles in two steps: First build a model which included only

real quantities, such as output and relative prices and then extend the model also to include nominal quantities such as money and absolute prices. After completing the first stage of this research plan, however, Kydland and Prescott concluded that the second may be unnecessary: 'business cycles can be explained almost entirely by just real quantities'.[3] They thus strengthened Long and Plosser's (1983) argument that business cycle fluctuations were not inconsistent with competitive theory that abstracts away from monetary factors and helped establish the 'Real' qualifier in Real Business Cycle theory. For reasons that have already been spelled out, we believe such definitive statements are at best premature and it remains to be seen to what extent purely real models will be able to explain an enriched set of stylized facts. More specific doubts have been expressed by Lucas (1985) who suggests that 'to account for depressions of the magnitude of those observed in the 1870–1940 period (and, I think, for more recent recessions as well) we need *either* much larger shocks than any that can be interpreted as "technology" *or* a propagation mechanism with much larger "multipliers" (...) [The problem] lies in accounting for large real fluctuations for "shocks" that are of the right order of magnitude'. The evidence on this issue is not yet clear. On the one hand, estimating the stochastic process of the Solow (1957) residuals is subject to sizable uncertainty. The estimate obtained by Prescott (1986) for the standard deviation of the technology shocks is consistent with the shock size necessary to account for actual business cycle fluctuations with some models [those for which the 'multipliers' are large enough, e.g., Hansen (1985)] but not others. In this sense the original Kydland and Prescott (1982) model is able to explain 70% of the fluctuations, leaving 30% to be explained by other factors not affecting the aggregate production function. As recalled by McCallum (1989), however, the literature discussing the Solow procedure has emphasized that the estimated magnitude of technical change is very sensitive to some of the hypotheses made.

On the other hand, even admitting that technology shocks models fall short of explaining observed fluctuations, the question remains as to whether monetary factors can fill the gap. From a recent review of various forms of evidence, Plosser (1989b) concludes that the case for a monetary theory of the cycle that relies on independent variations in the nominal quantity of money as an important business cycle impulse is weak. Not only do variations in nominal money explain very little of subsequent movements in real activity, but what explanatory power exists arises from variations in endogenous components of money. These findings appear consistent with a class of real business cycle models proposed by King and Plosser (1984).

[3]Introduction to the Fall 1986 issue of the Federal Reserve Bank of Minneapolis Quarterly Review, Vol. 10, no. 4, page 1.

They also accord with the conclusion of Kydland (1989), that in a calibrated business cycle model with money affecting economic activity either through price surprises or because the amount of desired liquidity services vary over the cycle, nominal shocks could not account for more than a small amount of the variability in real output and hours worked. This result is confirmed in a more recent study by Cooley and Hansen (1989) who explore an alternative monetary mechanism. These theoretical results are fully consistent with the identification of international business cycle regularities in the face of wide variations – in time and across countries – in the procedures, objectives, and conduct of national monetary policy.

Yet it must be acknowledged that none of the above models presumes the existence of nominal rigidities which we know are necessary for nominal shocks to translate into significant real variations. A first attempt in this latter direction is that of Cho and Cooley (1990). They study, in a standard RBC setting, the implications of nominal price and nominal wage contracts in the presence of money supply shocks. Their work suggests that while reasonable monetary shocks – working through nominal rigidities – can cause output volatility which resembles that of the U.S. economy, other aspects of the model data are substantially inconsistent with U.S. stylized facts.

The fact thus remains that money has yet to be integrated into business cycle models in a way that is consistent with the stylized facts of section 2. As in Cho and Cooley (1990), doing so may disturb some of the facts previously well accounted for in non-monetary models; it may as well enlighten our understanding of some outstanding puzzles.

3.3. Demand and supply shocks

As noted earlier, the overwhelming majority of RBC studies postulate technology shocks as the ultimate source of variation in the economy and many commentators have viewed this aspect of the basic RBC construct as least satisfactory. The objections given are generally one or more of the following:

(1) It is difficult to identify candidate technology shocks in the actual economy [Summers (1986), Mankiw (1989)] and the most frequently cited illustrations (oil shocks) are not technology fluctuations but actually factor price changes [McCallum (1989)].
(2) Furthermore, in order to achieve the dynamics required to statistically match the data, it is necessary for the postulated technology shocks to be highly persistent [King et al. (1988a)]. Highly persistent shocks are even more difficult to identify.
(3) Costello (1989) undertakes a Solow growth accounting study for a

selection of countries and for industries common to all of them; she finds that for a given industry there is not much correlation in productivity growth across countries, while a substantial fraction of the measured changes in productivity growth can be attributed to nation specific disturbances common to all industries in that country. Her results suggest that it may be unwarranted to interpret technology shocks as scientific productivity improvements since one would expect scientific advances within an industry to diffuse across borders fairly quickly.

(4) If we rather view technology shocks as sector specific and independent across sectors [Long and Plosser (1983)] – an entirely plausible hypothesis and in some sense the other extreme of the notion of an aggregate shock – what is the mechanism by which these sectoral shocks result in aggregate effects; that is, in a many sector economy such as the U.S., why are these shocks not diversified away to nothing economy wide?

The first three criticisms are relevant to the prior views of researchers on the functioning of the economy. In our eyes they are not substitutes for the type of accounting of residuals that was reviewed in the prior section. This approach may well lead to the conclusion that 'technology' shocks are not large enough and should be complemented with shocks from other sources, a point that has been forcefully argued by Eichenbaum (1991). Eichenbaum, notes, in particular, that the incorporation of labor hoarding phenomena substantially reduces the effectiveness of technology shocks in explaining output variation. This was also the original motivation for considering monetary business cycle models. Alternatively, 'theoretical priors' such as those discussed earlier may push researchers towards the construction of demand-shock RBC models more in conformity with their intuition and hopefully observationally equivalent to the original RBC models. This is our interpretation of Greenwood et al. (1988) to be reviewed presently. Finally, in perfect harmony with the RBC methodology, pure technology shock models may turn out to be falsified by certain stylized facts that would point towards taking explicit account of demand shocks in order to improve the descriptive power of the model. This is precisely Christiano and Eichenbaum's (1990) point whose argument is also outlined below.

Aiming at a Keynesian view of the shocks leading to business fluctuations, Greenwood et al. (1988) model the (iid, intertemporally) technology shift parameter as affecting only the productivity of new capital goods and not the productivity of existing installed capital. This disturbance is very different from the customary technology shock as, by effecting investment via shifts in the *future* marginal efficiency of capital, it is essentially a demand shock. Since productivity changes relate only to new capital, this appears a somewhat weaker requirement than the standard formulation in so much as it is well known that newly installed capital is frequently of uncertain initial

productivity. Using this construct, Greenwood et al. (1988) are able to match the sylized facts for the U.S. economy fairly well.[4]

Christiano and Eichenbaum's (1990) motivation is the near-zero correlation between hours and productivity, or hours and wages reported in section 2.3. They rightly observe that existing RBC models predict these correlations to be near one and suggest the most likely productive solution to this puzzle is the introduction of demand shocks along with technology shocks. Demand shocks are assumed to take the form of an uncontrolled stochastic process on government spending which in turn is modeled as an imperfect substitute for private consumption (private and public consumption yield different marginal utility). With this additional source of uncertainty, the authors are able to improve the performance of the basic model along the hours/productivity dimension by effectively increasing the elasticity of demand for labor. The ability of the model to explain the other important stylized facts of the business cycle remains robust to this modification. Christiano and Eichenbaum's and Christano's (1990) result is consistent with Prescott's view that technological shocks explain only about 70% of aggregate fluctuations and that other sources of uncertainty will be necessary in order to fully exploit the explanatory power of the stochastic growth paradigm.[5]

A few more comments are in order regarding technology shocks. The first is to note (this point will be elaborated upon in a later section) that non-Walrasian models with endogenous rigidities in general display proportionally much greater variation for the same level of technology shock than analogous Walrasian models, i.e., the propagation mechanism is more powerful in this model class. As a consequence, the magnitude of the technology shock required to produce the observed output variation is correspondingly reduced. In some sense, the smaller the size of the assumed shocks, the easier they are to accept. This trend can be observed if we compare the work of Kydland and Prescott (1982) and Hansen (1985); Kydland and Prescott (1982) (a fully Walrasian model) require a shock standard deviation of 0.0093 while Hansen (1985) (who excludes adjustment in the level of hours worked) requires only a standard deviation of 0.0071. Our work [Danthine and Donaldson (1991a)], in which labor wage rates are set contractually, requires an even smaller shock (0.0027). Mortensen (1990)

[4]Their results are, however, not exactly comparable to those we have presented earlier as they employ a different filtering methodology.

[5]In a companion paper, Aiyagari et al. (1990) omit technology shocks altogether and rely solely on shocks to government consumption (which is again modelled as an exogenous stochastic process with iid and persistent components). They explore the dynamics of the model vis-à-vis such issues as the equilibrium impact of permanent changes in government consumption on interest rates and the magnitude of the government spending multiplier. While they do not directly emphasize a comparison of the model's aggregate output statistics with those of the U.S. economy, its structural similarity to the earlier piece and their choice of calibration scheme ensure that its performance along the basic performance dimensions will be good.

makes a similar point in his model where the labor market is modeled as a search equilibrium. In a similar vein, Greenwood and Huffman (1990) demonstrate that the introduction of distortionary taxes and subsidies also dramatically increases the variability of the major aggregates arising from a given shock structure.

A response to the fourth criticism has been offered by Donaldson and Dutta. In a multisector economy, if shocks to various sectors are forecast one period in advance and capital therefore optimally assigned to the sector where the productivity shock is most favorable, Donaldson and Dutta (1989) and Dutta and Polemarchakis (1989) show not only that aggregate uncertainty can result where none existed before (without the forecasting), but also that the aggregate uncertainty will not disappear even as the number of sectors expands without bounds. This latter fact results from the concentration of new investment on the few sectors with the highest productivity shocks.

3.4. Modeling the labor market

The labor market stylized facts have been the principal focus of attention during the early stages of the RBC research program, and the resulting attempt to account for the employment variability puzzle (see section 2.3) provides a good illustration of the RBC methodology. Let us recall that for the U.S. economy, hours fluctuates proportionately almost as much as output and one and one half times as much as productivity (see table 1). This pattern is reversed in the basic growth model where both employment and productivity have a standard deviation which is about 50% of that of GNP. This discrepancy has been viewed as too large to be a result of measurement errors and thus falsifies the basic growth model. The response to this rejection has taken various forms. In their seminal article, Kydland and Prescott (1982) have questioned the time additive utility structure. Indeed, one interpretation of the observations is that real life worker–consumers are more willing to substitute labor and leisure intertemporally than what is allowed by the time additive utility function. Kydland and Prescott (1982) propose to capture this feature by having the representative household's period utility be a function of the market produced consumption good and a distributed lag of leisure taking the form

$$U(c_t, l_t) = U(c_t, 1 - \alpha n_t - (1-\alpha)\eta \sum_{J=1}^{\infty} (1-\eta)^{J-1} n_{t-J}),$$

where c_t is period t consumption, n_t labor provided in period t, and α, η are constants.

The second column of table 9 demonstrates that this alteration goes some

Table 8

Results from three models.

Variable	Kydland and Prescott model[a]		Hansen–Rogerson model[a]		Danthine–Donaldson non-Walrasian model	
	(a)	(b)	(a)	(b)	(a)	(b)
Output	1.76	1.00	1.76	1.00	1.76	1.00
Consumption	0.44	0.85	0.51	0.87	0.34	0.69
Investment	5.40	0.88	5.71	0.99	6.08	0.99
Capital stock	0.46	0.02	0.47	0.05	0.54	0.03
Hours	1.20	0.95	1.35	0.98	1.26	0.98
Productivity	0.70	0.86	0.50	0.87	0.61	0.91

[a]Data taken from Prescott (1986).

way towards resolving the puzzle.[6] The question remains, however, whether the labor supply elasticity implied by this formulation is confirmed in labor studies. While the answer is not unanimous, the dominant view from the literature [e.g., Ashenfelter (1984)] is that a proper calibration of the labor elasticity parameter would prevent a full resolution of the puzzle under this approach.

Fortunately, Hansen (1985) has shown that an alternative approach may be more fruitful. Following Rogerson (1988), he proposes to explore the consequences of admitting institutional indivisibilities in the labor supply decision that require agents to work either full time or not all. Hansen's approach was motivated by the observation (section 2.3) that most of the variation in aggregate hours arises from variation in the number employed rather than in hours worked per employed person. Workers are viewed as choosing jointly a probability of unemployment and a package of consumption and hours worked. Workers are thus perfectly insured against idiosyncratic employment uncertainty (all workers receive the same income irrespective of their employment state), though not against aggregate uncertainty. The striking result obtained with the Hansen–Rogerson construct is that the representative agent ends up behaving as though his period utility function were linear in leisure – for which the intertemporal elasticity of substitution is infinite – despite the fact that each individual household is endowed with a standard separable log linear function of consumption and leisure. The results of Hansen's model are reported in column 2 of table 8 On the bases of the limited set of stylized facts presented there, Hansen's results are about

[6]It should be noted, however, that these numbers result from a model which departs from the standard paradigm along several dimensions, including a 'time to build' feature and a variable work week of capital.

Table 9[a]

	Y	*PY*	*PC*	*C*	*I*	*S*	*G*	*X*	*M*	*M1*	*M2*	*RST*	*RLT*	*W*	*N*
1. Australia	59.3	59.3	59.1	59.3	59.3	59.3	59.3	59.3	59.3	57.1	57.1	69.3	57.1	61.3	70.3
	89.3	89.3	89.4	89.3	89.3	89.3	89.3	89.3	89.3	89.3	89.4	89.3	89.3	89.4	87.4
2. Austria	57.1	64.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	58.1	67.1	70.1	57.1	57.1
	88.1	88.1	89.1	88.1	88.1	88.1	88.1	88.1	88.1	89.3	89.4	80.4	86.4	88.2	89.4
3. Canada	61.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	67.1	63.1	57.1	57.1	57.1	57.1
	89.4	89.4	89.4	89.4	89.3	89.2	89.4	89.4	89.4	89.3	89.3	89.3	89.3	89.3	89.3
4. France	65.1	65.1	57.1	65.1	65.1	65.1	65.1	65.1	65.1	57.1	57.1	57.1	57.1	57.1	57.1
	89.3	89.1	89.4	89.1	89.1	89.1	89.1	89.1	89.4	89.3	89.4	80.4	89.3	89.2	89.1
5. Germany	60.1	60.1	57.1	60.1	60.1	60.1	60.1	60.1	60.1	57.1	57.1	57.1	57.1	57.1	57.1
	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.3	89.4	89.4	89.4	89.3	89.4
6. Italy	60.1	60.1	57.1	70.1	60.1	70.1	70.1	60.1	60.1	57.1	57.1	71.1	57.1	59.1	59.1
	89.1	87.3	89.4	89.3	89.3	89.3	89.2	89.3	89.3	89.3	89.4	89.3	89.3	89.4	89.4
7. Japan	57.1	57.1	57.1	57.1	57.1	57.1	65.1	57.1	57.1	57.1	57.1	57.1	66.4	57.1	57.1
	89.3	89.3	89.4	89.3	89.3	89.3	89.9	89.3	89.3	89.3	89.3	80.4	86.4	89.4	89.1
8. South Africa	60.1	60.1	57.1	60.1	60.1	60.1	60.1	60.1	60.1	57.1	58.1	57.1	57.1	–	61.1
	89.3	89.3	89.4	89.3	89.3	89.3	89.3	89.3	89.3	89.3	89.4	89.4	89.3	–	89.3
9. Switzerland	67.1	67.1	57.1	67.1	67.1	67.1	67.1	67.1	67.1	57.1	57.1	57.1	57.1	57.1	57.1
	85.4	85.4	89.4	85.4	85.4	85.4	85.4	85.4	85.4	89.3	89.4	89.4	89.4	89.4	89.3
10. U.K.	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	63.1	57.1	63.1	77.1
	89.2	89.2	89.4	89.2	89.2	89.2	89.2	89.2	89.2	89.3	89.2	89.3	89.3	89.3	89.2
11. U.S.A.	57.1	87.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1	57.1
	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.4	89.3	89.4	89.4	89.4	89.4	89.4

[a] *Y* denotes GDP, *PY* the GDP deflator, *PC* the consumer price index, *C* aggregate consumption, *I* aggregate investment, *S* aggregate savings, *G* aggregate government spending, *X* aggregate exports, *M* aggregate imports, *M1*, *M2* money supply measures, *RST* the real short terms rate, *RLT* the real long term rate (both on risk free government obligations), *W* the real wage, and *N* the level of employment.

as good as one could hope for, thus giving rise to Prescott's (1986) claim that 'there would be a puzzle if the economy did not display the business cycle phenomenon'. Yet, in our view, this should not the end point of the inquiry. Besides evaluating how well such a model is able to replicate other stylized facts, and indeed it is well known to fail in at least two respects [for instance, Christiano and Eichenbaum (1990) point out that hours and wages and productivity are (contemporaneously) correlated on the order of 0.9 in Hansen's model while being correlated close to zero for U.S. data; McCallum (1989) notes that the pattern of correlations of output with leading and lagging labor productivity is incorrect], one may want to search for alternative explanations for the same set of facts.

There has been a number of notable efforts in this regard, two of which are in the pure Walrasian tradition. Cho and Cooley (1989) develop a model in which agents are required to undertake both an hours worked decision and a labor force participation decision. They postulate a fixed (from the individual household's perspective) cost associated with the decision to participate in the labor market which is to be viewed as capturing the expense of replacing lost home production (child care, etc.). In equilibrium, this fixed cost becomes an increasing function of the participation rate. Cho and Cooley's formulation can be viewed as midway between the extremes of Kydland and Prescott (1982) and Hansen (1985). The former authors allow adjustment only in hours (everyone works) while the latter allows adjustment only in the participation rate; Cho and Cooley allow both. As a result, labor supply is more elastic vis-à-vis changes in the real wage. Unfortunately when they calibrate the model to match the variability of output, the improved performance of the model along the employment and productivity dimensions appears to come at the expense of insufficient variability in the other series. Furthermore, the correlation of hours with output is even greater than in Hansen's (1985) model.

Another interesting approach is the home production function agenda of Benhabib et al. (1990, 1991) and Greenwood and Hercowitz (1991). Benhabib et al. (1990, 1991) model home production explicitly by postulating the existence of a household production sector with access to a stochastic technology for the production of a 'home' consumption good. Working in the home sector is viewed as an alternative to working in the market sector where market goods (also consumed) are produced also using a stochastic technology. The idea these authors seek to exploit is succinctly expressed as follows: 'To the extent that individuals are willing to substitute between market and non-market activities at a point in time, then relative productivity differentials between the two sectors may induce substantial variability in market variables over time' [Benhabib et al. (1990, 1991)]. Relative to the standard paradigm, their model produces a greater elasticity of labor supply because the customary intertemporal substitution effects are reinforced by the

addition intratemporal (market work vs. home work) substitution effects. Using a carefully calibrated parameterization, Benhabib et al. are able to substantially increase the volatility of hours relative to output; the correlation of the average product and output is also substantially reduced vis-à-vis the one good growth paradigm.

The essence of the employment variability puzzle is the fact that quantities bear the brunt of the adjustment to fluctuations whereas Walrasian theory predicts that prices (and wages) should serve this function. This in turn suggests the incorporation of a non-Walrasian organization of the labor market as an alternative route to explaining the stylized facts. While this may be viewed as an anathema from the original RBC perspective, it is fully within the spirit of the RBC methodology. The main challenge to its implementation is in fact 'technical' rather than ideological. Indeed, while for a given preference and technology structure there is a generally accepted formulation of Walrasian equilibrium, there is no such corresponding non-Walrasian formulation. In some sense the lack of consensus in labor market theory is similar to that of monetary theory and the consequent attempts to merge that former literature with RBC theory suffer from the same handicaps.

These considerations notwithstanding, Danthine and Donaldson (1991a, b) propose a full-fledged dynamic RBC style model in which the equilibrium wage determination is largely non-Walrasian in nature. Their model is motivated by three principal observations: (1) for many workers, borrowing constraints severely limit the possibility of consumption smoothing over time; (2) for the fraction of the population working under contract, efficient risk and income sharing may thus be expected at least in part to occur via employer's wage policies; and (3) for workers in the casual labor market, this income sharing does not apply. For this latter group, however, most developed countries provide unemployment insurance mechanisms designed to prevent extremes of income fluctuation. Danthine and Donaldson's (1991a, b) paper can then be viewed as posing the following question: Assuming the outcome of these institutional arrangements corresponds to a socially optimal reallocation of income and risks, would the dynamic features of the economy bear any resemblance to the stylized facts?

To answer this question they propose a model in which the firms are owned by infinitely-lived dynasties of entrepreneurs (capitalists) who are entitled to the residual profits from production. These capitalists undertake the economy's investment and production decisions, and, in the RBC tradition, the firm's technology is subject to random technology shocks. Workers, by contrast, live a finite number of periods with the same number of workers being born and dying each period. There is thus a stationary population of workers, of which one half are viewed as 'young' unskilled apprentices and the other half as 'old' skilled workers. Every worker, young

or old, is assumed to supply one unit of labor inelastically in each period of his life.

It is then assumed that firms offer efficient labor contracts to old workers. Such contracts must clearly specify full employment since there is no disutility to work in their model. More importantly, they imply optimal risk sharing between the risk averse old workers and the less risk averse capitalists. Following Drèze (1989), Danthine and Donaldson (1991, 1992) further postulate the impossibility of contractual relationships between firms and young workers. They thus assume that for a portion of the labor force, efficient risk sharing cannot be achieved privately. Firms decide, on a purely profit maximizing basis, how much young labor to hire for the current period given their current capital stock and ex post to the realization of the value of the technology shock. In order to mitigate the considerable variability in young worker income that would otherwise ensue, a system combining a minimum wage with unemployment compensation financed by a tax on firm profits is postulated. The state contingent minimum wage and unemployment compensation are chosen so as to maximize a standard social welfare function.

The results of this exercise for a representative set of parameters are reported in the third panel of table 8. Along the variability dimension (column (a)), the model is seen to perform extremely well and, in fact, can be viewed as providing a resolution to the wage-employment variability puzzle. This appears even more striking if one recalls that the variability of young hours is twice the variability of total hours. At 2.52, it is significantly higher then the variability of output for the U.S. economy. With regard to correlations with output, the model performs equally well. These results are strongly suggestive that non-Walrasian features are fully compatible with the major stylized facts of the business cycle. Danthine and Donaldson (1990) provide added support for this assertion in a related piece which explores the efficiency wage perspective in the context of a RBC model.

4. Concluding comments

In this paper, we have argued that the major impact of the RBC literature has been to propose a new methodology for macroeconomics. This methodology is distinguished first by the importance it attributes to the empirical description of the phenomena to be explained and, second, by the use of this description in conjunction with 'quantitative theorizing', i.e., the construction of computable general equilibrium models whose characteristic statistics match those of the data. In accordance with this approach, we have first reported on the current state of knowledge concerning business cycle regularities and have concluded that additional empirical effort is called for in order to arrive at the appropriate basis for theorizing. We have then

examined the performance of existing models and evaluated the case for integrating monetary factors and demand shocks into them. Lastly we have reviewed the recent efforts to explain the employment variability puzzle, and have argued that the search for such a solution naturally leads to the incorporation of significantly non-Walrasian features into the RBC framework.

How successful has the RBC methodology been to date; that is, what proportion of the stylized facts has the theory thus far been able to explain satisfactorily? We pose this question with the recognition that, as part of the RBC research program, new stylized facts are continually being sought in order better to evaluate and refine the model paradigms. We also pose it with the added recognition that most RBC models have not used formal testing procedures when comparing their theoretical and empirical results, so that there may be disagreement as to model rejection criteria. More generally, the place of calibration exercises with respect to more traditional econometric testing procedures remains to be determined, and would deserve a full discussion for which space is lacking [for one perspective, see Kydland and Prescott (1991)]. On this point we are of the view that RBC models, being 'small', abstract formulations whose purpose is to provide intuition for economic mechanisms, are such that not much can be learned by submitting them to traditional econometric tests: The models are obviously 'wrong' and will be rejected by the data. Yet an appropriate econometric method designed to permit a formal comparison between empirical and model generated data and which can provide some insight as to the robustness of results vis-à-vis changes in parameter values is clearly called for. Such a method, based on Hansen's (1982) Generalized Method of Moments has been proposed recently by Christiano and Eichenbaum (1990), and we find ourselves in full agreement with its purpose. The task of implementing it in the different applications reviewed above is before us.

For the basic aggregates – consumption, investment, output and capital stock – the models to date perform quite well. With regard to the labor market, work remains to evaluate the competing theories articulated in the prior section. But as the current stylized empirical description of the labor market is rather crude (variation and correlation with output of total hours (perhaps quality adjusted) and average productivity) we look forward not only to a more refined, generally accepted empirical assessment of labor market dynamics but also the class of models best able to replicate it.

Despite the plethora of stylized international regularities considered earlier, most of the accomplishments to date have been provided in the context of closed economy macrodynamic modelling. Since the intertemporal reallocation of consumption in a real world economy is achieved not only via domestic physical capital investment (the driving force behind most RBC dynamics) but also by the accumulation/decumulation of foreign assets to

finance trade, RBC theory must satisfactorily explain not only observed savings/investment correlations but also the trade balance. Open economy macrodynamics is still in its infancy though very substantial progress in being made [e.g., Backus et al. (1989b)]. In the pure RBC tradition, the principal research strategy thus far has been to examine international issues in the context of a two agent Pareto optimal formulation. One of the central problems remaining appears to be to explain the high savings/investment correlation within nations without having the model simultaneously imply much higher cross country consumption correlations than what are actually observed [see e.g., Backus et al. (1989a) and Baxter and Crucini (1989)] – the latter being a consequence of the high level risk sharing necessarily present in the optimum formulation. A number of partial solutions to this puzzle have been proposed including the provision for non-traded goods [Ravn (1990)] and non-separable preferences for consumption and leisure [Devereux et al. (1990)].

By their very nature RBC theories are purely competitive in the classical sense; there is no modelling of industrial organization or strategic behavior on the part of firms. This focus on competitive theorizing is the natural first step by virtue of its well known optimality properties and relative ease of computation. Some have claimed, however, that models with elements of monopoly or monopolistic competition can replicate the stylized facts as well or better than competitive models. In addition, a non-trivial industrial structure will bring with it a further set of stylized facts – such as observed regularities in the size distribution of firms – which will impose added discipline on the models. To date, Hall (1988) has proposed a dynamic model of fluctuations with a monopolistic and competitive sector driven by preference shocks. His formulation has not yet been subject to the RBC methodology, however. Rotemberg and Woodford (1989) have proposed a dynamic general equilibrium model with industry price collusion and have argued that such features enhance the model's ability to explain the manner by which the economy responds to aggregate demand shocks. Again, their model has not been subject to a full dynamic analysis. Cho (1990) examines a number of market structures in the context of a fairly specialized RBC model and finds that whereas the propagation mechanism under oligopoly (with at least ten firms) is sufficient to generate an appropriate level of variability, this is not the case under monopoly. He notes that increasing competition as a result of increasing the number of firms is a powerful way of augmenting fluctuations, but his results strongly depend upon the size of demand and supply elasticities.

We next turn to the place of government in RBC formulations and the issue of stabilization policy. In most RBC models analyzed thus far in the literature government plays an extremely passive role if it is present at all [an exception is Eichenbaum and Christano (1990) where uncertainty in govern-

ment purchases is one of the principal determinants of model dynamics; they do not consider stabilization policies, however]. This state of affairs is partially a reflection of the dominant RBC philosophy, which views cyclical fluctuations as the result of agents' optimal responses to exogeneous uncertainty. In the absence of distortionary taxes and subsidies, economic stabilization would thus be welfare diminishing. For an economy with pervasive distortionary taxes and subsidies, however, it is less clear that stabilization policy has no role to play. This is the perspective adopted in Greenwood and Huffman (1991) who demonstrate, in a model with distortionary taxes and subsidies, that a program of output increasing subsidies paid to firms in low output states has the effect of increasing welfare by an amount equivalent to a (uniform across all states) consumption increase of 0.68% of steady state output. They acknowledge, however, that such gains in welfare are very small relative to the gains achievable through the full elimination of the distortions. This suggests that a significant role for stabilization, should one arise, will go only hand in hand with an accepted determination of the cost of fluctuations that exceeds the current estimates. The latter are astonishingly low [see, e.g., Lucas (1987) and Imrohoroglu (1989)].

Perhaps the most frustrating setbacks to the progress of RBC theory have been observed at its interface with finance. As noted earlier, we await satisfactory explanations for such basic phenomena as the term structure of interest rates and the magnitude of the equity premium. While a number of resolutions to the latter 'puzzle' have been proposed (for example, nondiversifiable risk [Mankiw (1986)], small probability of events of ruin [Reitz (1988)], heterogeneous beliefs [Abel (1988)], habit formation [Constantinides (1990)], time varying lower bound on consumption [Nason (1988)], none have met with general acceptance. More importantly, none of these resolutions is presented in the context of a model which simultaneously replicates the stylized facts of the business cycle. In a recent paper, Aiyagari and Gertler (1991) incorporate differential transaction costs for different assets and an absence of insurance markets for idiosyncratic income fluctuations into a stochastic asset pricing model and obtain not only a satisfactory equity premium but also a near zero real risk free rate and a pattern of transaction velocities for different assets which mirrors the stylized facts for the U.S. Their results, while promising, need to be extended to a production setting consistent with the other business cycle stylized facts. Despite the enormous research efforts devoted to an analysis of the term structure, many anomalies also remain. For one example, dynamic asset pricing models in the RBC tradition have yet to explain satisfactorily the time varying risk premium in the term structure [Backus et al. (1989b)]. We view the business cycle/finance interface as a particularly promising field of research, of interest to both finance and macroeconomics professions.

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