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US, JAPAN AND THE EURO AREA: COMPARING BUSINESS-CYCLE FEATURES

BY PETER MCADAM

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Contents

Abstract
There has been much discussion of the differences in macroeconomic performance and prospects between the US, Japan and the euro area. Using Markov-switching techniques, in this paper we identify and compare specifically their major business-cycle features and examine the case for a common business cycle, asymmetries in the national cycles and, using a number of algorithms, date business-cycle turning points. Despite a high degree of trade and financial linkages, the cyclical features of US, Japan and the euro area appear quite distinct. Documenting and comparing such international business-cycle features can aid forecasting, model selection and policy analysis etc.
JEL: C32, F20
Keywords: Business cycle, Markov switching, Synchronization, Turning Points.

Non Technical Summary

Differences in economic performance between the US, Japan and the European Union have been the subject of much debate. Though these economies might be considered similar – being large, high-income and relatively closed – the literature has generally stressed key macro-economic differences such as differences in growth performance, unemployment persistence, institutional features, “new economy” effects etc. This paper further investigates such differences from a business-cycle viewpoint. Whilst the literature on business cycles is huge (especially relating to the US), directly comparing the business-cycle features and economic linkages of the US, Japan and the new euro area has yet to be done. That is the purpose of this paper. Such information – other than contributing to structural debates – can also aid the development of business-cycle models and inform policy makers’ priors about the cyclical evolution of theirs and neighboring economies. We analyze business-cycle features in three steps. First, their basic features: how long do countries spend in expansion, what are the characteristics of the phases of the cycle, are there asymmetries etc? For this, we model growth as a Hamilton (1990) Markov process. Second, we date business-cycle turning points, using, for robustness, a variety of algorithms in addition to that of the Markov process and examine synchronization between international cycles.

Our conclusions include the following.

Despite sizeable trade and financial linkages, the cyclical features of US, Japan and the euro area are quite distinct. The US has been characterized by more frequent but milder downturns relatively to Japan or the euro area. In terms of the “new economy”, the US has, uniquely, witnessed a large reduction in output volatility from 1984 onwards but with no apparent change in average growth. The Japanese cycle is characterized by, on average, strong if highly volatile growth with, notably, three very short contractions. The euro area has witnessed broadly stable growth but with no significant reduction in volatility. Like Japan, it is characterized by relatively few, deep but short-lived contractions. On asymmetries, all economies face the basic feature of differences in regime duration. The euro area appears to be characterized by both Turning-Point Sharpness (as does the US) and Deepness. The asymmetries in the Japanese data – essentially driven by some large single-period downturns (e.g., 1974:1) – are necessarily not detected by the regime shifts in the Markov process.

The paper provided business-cycle chronologies for each of the countries based on three algorithms; turning points appeared quite robust across methods. This helps shed light on international interdependencies. The strongest period of turning point congruence appears broadly after the first oil shock (1973-75). Overall, however, the case for a genuinely common-sourced international business cycle is mixed. Before the 1990s, cycles appeared somewhat synchronous. Asymmetric shocks or genuine decoupling thereafter dominate. Our results thus lend weight to the commonly expressed conjecture that the 1990s onwards might be considered as a period of global business-cycle decoupling. The evidence for cycle correlation, however, appears highest in periods of above-average expansion.

1. Introduction

Differences in economic performance between the US, Japan and the European Union have been the subject of much debate (e.g., Mundell, 1998). Though these economies might be considered similar – being large, high-income and relatively closed – the literature has generally stressed key macro-economic differences such as differences in unemployment persistence, León-Ledesma (2002), wage bargaining, McMorrow (1996) and factor markets, Blanchard (1997), institutional features, Blanchard and Wolfers (2000), "new economy" effects, Temple (2002), the scope for policy co-operation gains, Hughes-Hallett (1987) etc. **Table 1** overviews such features. For instance, key similarities include similar population sizes (at least for the US and euro area), relatively closed economies (with the euro area the most open) and a sectoral concentration in Services; whilst key differences include higher unemployment in the euro area (with the US having the highest participation rate) and higher public and private debt in Japan (though buttressed against higher savings and current account surpluses). Thus, alongside strong financial, policy and trade linkages, sizeable heterogeneity exists between these three areas.

This paper further investigates such differences from a business-cycle viewpoint. Whilst the literature on business cycles is huge (especially relating to the US), directly comparing the business-cycle features and economic linkages of the US, Japan and the new euro area has yet to be done. That is the purpose of this paper. Such information – other than contributing to the above debates – can also aid the development of business-cycle models and inform policy makers' priors about the cyclical evolution of theirs and neighboring economies.

We analyze business-cycle features in three steps. First, their basic features: how long do countries spend in expansion, what are the characteristics of the phases of the cycle, are there asymmetries etc? For this, we model growth as a Hamilton (1990) Markov process. (Section 3). Second, we date business-cycle turning points, using, for robustness, a variety of algorithms in addition to that of the Markov process and examine synchronization between international cycles (Section 4). Section 5 concludes.

2. Data

We use seasonally-adjusted, quarterly real GDP growth rates from 1970:1 to 2001:4 for the US and Japan (OECD data) and the euro-area (Fagan *et al.*, 2001)[1]. **Graphs 1** and **Table 1** show the real growth rates over these three decades**.** Driven mainly by its performance in the 1970s and 1980s, Japan has had amongst the highest if most volatile growth. For instance, it experienced extremely large downturns after the first oil shock (-3.5%) as well as in mid-1997 (-3.2%). From the 1990s onwards, notably, Japan has experienced historically very low but still highly volatile growth. The US, by contrast, has had a fairly constant mean growth but a significant reduction in volatility over time – with the pre- and post 1984 (where volatility halved from 1.2 to 0.5) notable.[2] Average growth for the euro area is the weakest but the least variable.

3 (Markov-Switching) Business-Cycle Features

Following Hamilton (1989), we model the business cycle as a Markov-switching (MS) process. The method has a number of well-known advantages, e.g., Raj (2002). First, the explicitly non-linear Markov approach matches the inherently non-linear features of the business cycle (e.g., that expansions last longer than contractions). Second, MS models allow for the direct testing of different types of business-cycle asymmetries (e.g., that troughs are deeper than peaks). Finally, using the associated regime probabilities, we can infer business-cycle turning points.

The MS model for *m* states, $m \in [2, \infty)$, for output growth Δy_t can be represented as:

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[1] Fagan *et al.* (2001), Annex 2 describes the construction of the euro-area data.
[2] Recent US growth patterns are discussed in, e.g., McConnell and Pérez-Quirós (2000), Stock and Watson (2002).

$$\Delta y_t = \mu(s_t) + \sum_{i=1}^{q} \phi_i \left[\Delta y_{t-i} - \mu(s_{t-i}) \right] + \varepsilon_t \tag{1}$$

Where $\mu(s_t)$ is the mean growth rate in state $s_t \in [1, m]$, ε_t is a disturbance term with (possibly state-dependent) standard error σ and ϕ_i are auto-regression parameters.[3] In the context of Hamilton's model, m=2 implying $\mu_1 < 0 \left(\mu_2 > 0 \right)$ denotes mean growth rates in "contractions" ("expansions") and errors are state-independent. The notable characteristic of such models is the assumption that the unobservable realization of the state, s_t, is governed by a discrete-time, discrete-state Markov stochastic process defined by the transition probabilities,

$$\Pr(s_{t+1} = j \mid s_t = i) = \rho_{ij}, \sum_j \rho_{ij} = 1, \; \forall i, j \in [1, m] \tag{2}$$

Thus, s_t follows a Markov process with the transition probabilities matrix, P:

$$P = \begin{bmatrix} \rho_{11} & \rho_{12} & \cdots & \rho_{1m} \\ \rho_{21} & \rho_{22} & \cdots & \rho_{2m} \\ \vdots & \vdots & \ddots & \vdots \\ \rho_{m1} & \rho_{m2} & \cdots & \rho_{mm} \end{bmatrix} \tag{3}$$

We estimate using the EM algorithm (Hamilton, 1990) and assign an individual observation x_t to the state m with the highest "smoothed" probability: $m^* = \arg\max_m \Pr\left(s_t = m \middle| x_T, x_{T-1}, \ldots, x_1 \right)$.

Table 2 shows parameter estimates, transition probabilities ρ_{ii}, standard errors σ_i and proportion ξ_i (and duration D_i) measures for each state and **Graphs 2** show the smoothed probabilities. For the US and Japan (euro area), tests suggested that variances are state dependent (independent) – although we show both cases for the US. Results suggest that mean growth rates in contractions (expansions) for the US, Japan and euro area are, respectively, -0.26% (1.0%), -0.33% (0.77%) and –0.70% (0.71%).[4] The probability that expansion will be followed by another quarter of expansion is around 0.95 in each country. In the US, contractions (expansions) last on average 4 (16) quarters and in Japan and the euro area, respectively, 1 (19) and 2 (18) quarters.[5] Furthermore, the US, Japan and the Euro area spend respectively 79%, 95% and 90% in an expansionary phase.

Returning to equation (1), whether state-dependent variance is considered for the US is important. If we impose state-independent variance (Model *A*), the Markov process tracks the business cycle in the customary manner. Allowing for the statistically significant state-dependent variance (Model *B*), however, this traditional classification breaks down. The decline in output variance is so dramatic that it overwhelms the conventional classification and we are left with a break into an "absorbing" state. The first, high-volatility state (σ = 1.16, 1970-1984:1), followed by a low-volatility state (σ = 0.51) thereafter.[6] Furthermore, a LR test could not reject equality of means across the variance breaks. This suggests that, irrespective of what caused changes in the early 1980s – "new economy"; improved monetary policy or inventory structure; favorable

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[3] Here, lag length q was chosen on the basis on conventional criteria; details available.

[4] The US results benchmark relatively well with Hamilton's (1989) results (1952-1984): $\mu_1 = -0.36$ and $\mu_2 = 1.16$ for durations of 4 and 10 quarters respectively. Extending the sample on from that exercise, however, highlights two significant features: (a) the long period of uninterrupted expansion from the early 1990s and (b) the reduction in US growth volatility from the early 1980s onwards. The first point contributes to a near doubling of the duration of expansions but, since we omit the expansionary 1950s and 1960s, slightly lower mean expansion rates. On point (b), recall that Hamilton assumed state-independent variances.

[5] Alternatively, the ratio of expansion to contractions is 3.8 (US), 19 (Japan) and 9.5 (euro area) quarters.

[6] Thus, our findings confirm McConnell and Pérez-Quirós (2000) (who found a variance break in 1984:1 and attributed it to a reduction in durables' output volatility). Koop and Potter (2000) similarly suggest a break in the early 1980s.

supply shocks and demographics; sectoral shifts [7] – its effect was firmly on the *second* rather than the first moment of US output growth.

Forms *A* and *B* can be combined if we model the switch in mean and variance in the Markov process separately (McConnell and Pérez-Quirós, 2000) – results of this "augmented" model are presented in the Appendix. Doing so for the US, largely separates out and preserves the traditional business-cycle turning points and the early-1980s variance break – the results across both methods (Tables 2 and 1A) are quite consistent. Doing so for Japan reveals a high volatility regime lasting from 1970:3 – 1975:1 and then from 1997:1 – 2001:4 – although again we seem to underestimate contractions.

3.2 Business-Cycle asymmetries

As noted earlier, the MS approach allows for testing of business-cycle asymmetries. Contractions clearly differ from expansions in terms of their relative durations, but two additional concepts of asymmetry are relevant in the MS context: (1) turning point asymmetry (Sharpness) and (2) Deepness. McQueen and Thorley (1993) test $H_0 : \rho_{12} = \rho_{21}\,(\text{Non}-\text{Sharpness})$ against $H_1 : \rho_{12} > \rho_{21}\,(\text{Sharpness})$: i.e., given *m*=2, Sharpness implies that the probability of moving from a low- to a high-growth state exceeds the reverse probability.[8] Deepness (Sichel, 1993) refers to whether troughs (peaks) are deeper (shallower) than peaks (troughs). "Depth" of contractions will appear as negative skewness; x_t is non-deep *iff*

$E\left[(x_t - E(x_t))^3\right] = 0$. In addition, we provide some standard moment metrics of the data itself.

[7] For an overview, Stock and Watson (2002).
[8] I.e., Sharpness asymmetry implies that troughs are sharp and peaks more rounded.

The mapping between asymmetries in the data and those found by the Markov process is relatively good, see **Table 3**. Skewness (and deepness essentially) cannot be rejected at 5% for the euro area. The euro area is also characterized by Sharpness. The US cycle does not appear to be characterized by statistically significant skewness but Sharpness cannot be rejected (at least) at the 6% level. The apparent asymmetries in the Japanese cycle, however, are not captured by the Markov process. The test, however, analyses the asymmetry of the Markov-chain component only. For Japan, regime 1 therefore essentially consists of only a few extreme values and so the regime shifts can hardly be responsible for the observed skewness of data.

3.3 Three-State Case

It has been argued (e.g. Sichel, 1994) that a three-state Markov process fits business-cycle data better around a more intuitive classification: contraction, high and moderate growth. Notwithstanding, this has some appeal for the Japanese cycle since the two-state process clearly underestimates the strength of contractions. Further, p_{11} (the probability of entering and remaining in a contraction) is extremely small (lasting 1 quarter). Such a brief transition might be considered less a state per se but more an extreme value – perhaps separating out different growth regimes. Indeed, Japanese post-war history is often divided into three regimes (e.g., Lincoln, 2001): high pre-1973 growth, moderate 1973-1991 growth and low growth thereafter. The three-state case (**Table 4**, **Graphs 3**) correctly classifies the 1974 and 1997 downturns, captures the pre- and post-1973 "structural break" well into a near absorbing state of "moderate" growth but does not detect a new state post-1991 when the asset bubble, that emerged in the mid-

1980s, burst. [9] For the US three-state case, we again see that since 1984 there has been no contractionary episodes (excepting 1990:2–1991:2) although post-1984, there is no re-emergence of the (third) high-growth state thereafter.[10] Interestingly, there is full probability of contraction towards the end of the horizon – this compares with the two-state case where it is only around 0.8. For the euro area, we see that the low growth periods have lasted on average 1.6 quarters and essentially been restricted to the first and second oil shock, some turbulence in the mid-1980s and the early 1990s (inter alia, German re-unification). Somewhat like Japan, its period of highest growth was in the 1970s but also from the late 1980s until reunification. Overall, results suggest that mean growth rates in low, (moderate) and {high} growth regimes for the US, Japan and the euro area are respectively: -0.28%, (0.86%), {1.87%}; -2.64%, (0.67%), {1.29%}; and -0.66%, (0.55%), {1.25%}.

Whether the three-state case outperforms the two-state one is open to debate[11]. Though there is a statistical separation (at 1%) between moderate and high-growth states for the US and euro area, for Japan it occurs only at the 15% level – due to the variance of the high-growth state. However, the three-state case better matches Japanese downturns. Overall, however, it is widely recognized that Japanese GDP growth data has little cyclical content[12] – its MS results are therefore tentative.[13]

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[9] Note, we assumed for illustrative purposes regime-independent variances. Results with regime-dependent errors are available. We have also estimated a four-state case for Japan; details available.

[10] Thus, the three-state case confirms our earlier results that the "new economy" affected the second rather than the first moment of US output growth.

[11] We also used Baele's (2002) Regime Classification Measure to infer the associated probabilities attached to different regimes. However, the test proved inconclusive. Details available.

[12] We are very grateful for discussions on this issue with Yasuaki Kodama (Leader of the Economic and Social Research Institute, Japanese Cabinet Office). Their method is to date cycles by the application of the Bry-Boschan algorithm to Diffusion Indexes.

[13] As additional evidence for Japan, we also estimated the "switching intercept" model:

$$\Delta y_t = v(s_t) + \sum_{k=1}^{K} \alpha_k \Delta y_{t-k} + \varepsilon_t, s_t = 1, \ldots, m. \quad (1')$$

4 Cycle Synchronization

Our previous business-cycle analysis inevitably raises the question of whether international cycles are (or have been) synchronized. This, in turn, can shed light on international linkages. Examining cycle synchronization between the US, Japan and the euro area, however, is problematical due to the absence of a common dating method like the NBER methodology (which is multivariate and judgmental). However, Harding and Pagan's (2003) (quarterly) extension of the well-known Bry-Boschan (1971) algorithm forms a good approximation. To date cycle turning points, we therefore employ their algorithm alongside the popular "two-quarters" rule[14] as well as that predicted by our earlier MS regressions (of Tables 2, 3) [15]. By employing three different dating algorithms, we thus hope to lend robustness to our analysis. Indeed, relying solely on MS smoothed probabilities to date turning points, risks biasing cycle identification since it does not impose the censoring rules (i.e., phase and duration separations) inherent in the first two algorithms.

Table 5 shows the results of the different dating algorithms. For the US, there appear to be around five full cycles – comprising the two oil shocks, downturns in the early 1980s and early 1990s and the most recent contraction. In most cases, there is an exact match up with the NBER chronology. Furthermore, the different algorithms match one another relatively well – for example, all algorithms agree on the 1990:2-1991:1 cycle. In the euro area – where there appear

As before, results favor the three-state case. This model shares similar characteristics to the conventional three-state mean-switching case – equation (1) – in terms of, for instance, attributing a small duration to contractions (one-quarter). Notably, however, the proposition that troughs are deeper than peaks (i.e., deepness) is not rejected as it is in other specifications.

[15] We use the smoothed probabilities to infer turning points. For instance, in the two-regime case, periods with the smoothed probabilities of $s_t = 2$ greater (less) than 0.5 are likely to be in the state of high (low) growth. Further, we use the rule that the last period with a smoothed probability greater (less) than 0.5 is taken as the peak (trough). As is standard in MS results – being motivated purely by cut-off points in the smoothed probabilities – we do not impose the same censoring rules (i.e., phase and duration separations) inherent in the first two algorithms. Consequently, the MS processes appear to upwardly bias cycle identification: for instance in the euro-area case the MS identifies three extra cycles over the mid-1980s that other algorithms do not.

to be around three cycles – there is a high degree of consensus over the turning points. For instance, all algorithms capture the cycles starting in 1974:3, 1980:1 and 1992:1. However, the turbulence of the 1980s is necessarily captured more fully by the MS model than in the other two (censoring) algorithms. For Japan, the first two rules point to two cycles in the 1990s, whereas the MS results specifically identifies the first oil shock. [16]

Thus, our different algorithms and the Markov process (**Graphs 2, 3**) track actual cycles reasonably well. From this, we might infer something about the strength and nature of international linkages and interdependencies. For instance, common contemporaneous turning points for the US and euro area comprise 1980:1 (peak) and 1975:1, 1980:3 and 1982:3 (troughs). Whilst the US and Japan have only 1973:4 (peak) in common. Japan and the euro area share 1974:3 (peak) and 1993:1 (trough). Thus, the peak around the first oil shock was common to both the US and Japan (1973:4) whilst lagged for the euro area (1974:3). However, the euro area (and seemingly Japan) had a shorter contraction than the US (both having reached the trough by 1975:1). Furthermore, the US and the euro area had identical cycles around the second oil shock.

However, the seemingly high degree of business-cycle homogeneity that characterized earlier periods weakened after the 1990s; whilst the early 1970s and 1980 contractions (the first and second oil shocks) were globally quite synchronous, the 1990-91 US recession did not carry over to the euro area or Japan. This apparent break can plausibly be attributed to country-specific shocks – monetary policy shocks (and the first Gulf war) in the US in 1990-1991; German reunification (1992-1993) (which, through trade and financial linkages, had a major effect on the

[16] Though there have been attempts to (monthly) date both the Japanese (Cabinet Office: http://www.esri.cao.go.jp/en/stat/di/011221rdates.html) and euro-area cycles (Altissimo *et al.,* 2001), these refer to the *deviation* rather than (as here) the *classical* cycle and are thus not comparable. The classical cycle is in the NBER tradition and refers to absolute declines in activity, the *classical* cycle. The deviation or growth cycle refers to movements around "trend".

euro area); and the bursting of the Japanese asset bubble (1991 onwards) and the effect of its consumption-tax hike in early 1997.[17] Furthermore, whilst the US experienced an unprecedented long expansion from 1992 onwards, Japan faced chronically low growth in the 1990s. Re-unification aside, the euro area has enjoyed normal, "moderate" growth from 1987 onwards. The 1990s may therefore be considered as a period either where global business-cycle (quasi) synchronization broke down or, alternatively, where highly country-specific shocks impacted. The most recent downturn (i.e., from 2001 onwards), however, may come to be seen as a renewed period of global synchronization (e.g., Helbling and Bayoumi, 2003).

Consequently, the case for synchronicity appears mixed. In addition, **Graphs 4** show the rolling cross-correlation of growth rates: with the possible exception of Japan (in the 1990s), the correaltions appear quite stable but low–valued.[18] **Table 6,** presents additional, more formal, metrics: the percentage of time countries are in the same phase (Concordance) and its standardized variant (which can be interpreted as a t-stat for the null of independence)[19] as well as correlations of the smoothed probabilities. Though the percentage of time that countries are in a common phase is high, there is only significant concordance between the US and the euro area. The correlation of the smoothed probabilities, furthermore, suggests that the maximum correlation occurs in high-growth periods.[20] Thus, although there is an international business cycle in the sense that output growths co-move over time, our analysis – in line with others, e.g.,

[17] For a discussion of such differential shocks, e.g., IMF (2001).

[18] The cross-correlations over the full sample are US-Japan (0.216), US-euro area (0.245), Japan-euro area (0.261). The same pattern as **Graphs 4** emerges for the smoothed probability correlations. Details available.

[19] This de-means the concordance index and divides by its estimated Newey-West standard error.

[20] Although correlating the MS smoothed probabilities is a common synchronization metric, its use is somewhat speculative since they imply a contemporaneous correlation but, also, since the proportion of time that countries are in an expansion is high, the correlation would be high even if these countries were independent.

Canova and de Nicoló (2003) – suggests that this correlation is not substantial but peaks during expansionary periods. [21]

5 Conclusions

Understanding the economic linkages and business-cycle features of the US, Japan and the new euro area is (and will be of) crucial importance for policy makers. Documenting and comparing such features can aid analytical forecasting, conjectural analysis, model selection [22] and policy analysis etc for instance. This paper has made a first-pass at directly comparing such features. Specifically, we conclude:

– Despite sizeable trade and financial linkages, the cyclical features of US, Japan and the euro area are quite distinct.

  - The US has been characterized by more frequent but milder downturns relatively to Japan or the euro area. The average duration of its contractions is around 1 year. In terms of the "new economy", the US has, uniquely, witnessed a large reduction in output volatility from 1984 onwards but with no apparent change in average growth.

  - The Japanese cycle is characterized by, on average, strong if highly volatile growth with, notably, three very short contractions (of average duration, 1 quarter). Japanese output

[21] More fundamentally, if international business cycles are mainly due to common sources, then there should be high contemporaneous correlation of shocks and effectively no evidence of Granger (block) causality between countries. Thus, as an additional exercise (unreported but available), we conducted tests on a reduced-form three-country VAR. Evidence suggests that the US (Block) Granger causes the output growths of Japan and the euro area but not the reverse. Testing for the significance of the contemporaneous correlation of output shocks – i.e., for the diagonality of the VAR covariance matrix – we could not reject orthogonality. Thus, shocks among the countries do not appear significantly contemporaneously correlated.

[22] For a recent exercise in modeling US, Japan and euro area linkages, see Coenen and Wieland (2003).

growth has little cyclical content in the sense that it is dominated by large single-period contractions. Nevertheless, by using two and three state cases as well the "augmented" model, we can claim some success in capturing key features such as the strength of the downturns and the periods of extreme volatility periods. In particular, the pre-1975 and post 1997 periods were associated with very high output volatility.

- The euro area has witnessed broadly stable growth but with no significant reduction in volatility. Like Japan, it is characterized by relatively few, deep but short-lived contractions (of average duration, 2 quarters). Further work, however, might seek to address the question of whether euro area countries (or specific sectors) have experienced the kind of volatility breaks witnessed by the US.

– On asymmetries, all economies face the basic feature of differences in regime duration. The euro area appears to be characterized by both Turning-Point Sharpness (as does the US) and Deepness. The asymmetries in the Japanese data – essentially driven by some large single-period downturns (e.g., 1974:1) – are necessarily not detected by the regime shifts in the Markov process.

– Whilst two- or three-state Markov processes fit US and euro-area data well, the three-state case suggests itself for Japan since it matches downturns better and at least one of the states appears to act as a separating mechanism between the different states. This is corroborated in that Japanese growth is, historically, usually divided into three or more regimes. More generally, however, characterizing the Japanese cycle using GDP data is highly problematic.

- The paper provided business-cycle chronologies for each of the countries based on three algorithms; turning points appeared quite robust across methods. This helps shed light on international interdependencies. The strongest period of turning point congruence appears broadly after the first oil shock (1973-75).

– Overall, however, the case for a genuinely common-sourced international business cycle is mixed. Before the 1990s, cycles appeared somewhat synchronous. Asymmetric shocks or genuine decoupling thereafter dominate. Our results thus lend weight to the commonly expressed conjecture (e.g., IMF, 2001) that the 1990s onwards might be considered as a period of global business-cycle decoupling. The evidence for cycle correlation, however, appears highest in periods of above-average expansion.

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Table 1—Descriptive Statistics (2001)

	US	Japan	Euro Area
Population and Labor Force			
Population (Mn.) (1)	284.8	127.3	306.6
Labor Force Participation Rate (%) (2)	76.8	62.0	67.4
Unemployment Rate (Share of civilian labor force) (%) (3)	4.8	4.6	8.0
GDP and Value Added (PPP Conversion)			
GDP (Euro billions) (4)	8700.9	2919.6	6827.7
GDP per capita (Euro Thousands) (5)	30.5	22.9	22.3
Share of World GDP (%)	21.4	7.3	15.9
Value Added by Sector (%)			
Agriculture, Fishing, Forestry (6)	1.4	1.3	2.4
Industry (Including Construction) (7)	21.6	30.4	27.7
Services (Including Non-Market Services) (8)	77.0	68.3	69.9
Households			
Gross Saving (9)	12.6	14.4	13.3
Gross Fixed Capital Formation (10)	6.1	8.1	9.3
Gross Debt Outstanding (11)	103.9	117.9	75.9
Public Sector			
General Government Expenditure (12)	31.6	38.7	48.8
Surplus (+) or Deficit (-) (13)	-0.5	-6.1	-1.5
Gross Debt Outstanding (14)	44.8	134.6	69.2
External			
Exports of Goods and Services (15)	9.9	10.7	19.8
Imports of Goods and Services (16)	13.5	10.1	18.7
Current Account Balance (17)	-3.9	2.1	-0.2
Openness: (Exports + Imports) / 2	11.7	10.6	19.25
Mean Growth (St. Dev.)			
1970-2001	0.750 (0.887)	0.764 (1.023)	0.626 (0.608)
1970:1 – 1979:4	0.837 (1.101)	1.125 (1.137)	0.880 (0.726)
1980:1 – 1989:4	0.735 (0.966)	0.948 (0.692)	0.538 (0.572)
1990:1 – 1999:4	0.692 (0.589)	0.317 (1.011)	0.493 (0.463)
1970:1-1983:4	0.716 (1.194)	0.982 (1.006)	0.695 (0.707)
1984:1-2000:4	0.822 (0.533)	0.662 (0.978)	0.601 (0.516)
Max Growth (18)	3.775 {1978:2}	3.282 {1973:1}	1.986 {1970:2}
Min Growth (18)	-2.060 {1980:2}	-3.489 {1974:1}	-1.332 {1974:4}

Source: ECB.

Notes: % of GDP unless otherwise stated. Data are in current prices. (1) Euro area: annual average; US: mid-year; Japan: 1st October, (2) Ratio of the labor force to the working age population (age 15 to 64). US: the proportion of the civilian non-institutional population 16 to 64 years of age, either at work or actively seeking work. Annual average. (3) Standardized Unemployment Rate according to the ILO guidelines. Annual average. (4) Data for the US and Japan converted into euro at OECD purchasing power parities (PPPs) for 2001. (1 EUR = 1.1587 USD = 173.8123 JY). (5) Data for the US and Japan converted into euro at OECD PPPs for 2001. (6-8) Sectoral classification: euro area: Statistical Classification of Economic Activities in the European Community, Revision 1 (NACE Rev.1); US: North American Industry Classification System (NAICS); Japan: National Accounts. 9-11 Households include non-profit institutions serving households (NPISHs). Contrary to the euro area and Japan, the US definition does not include sole proprietorships and partnerships. (9-11) The ratio of disposable income to GDP is, for the euro area, 71.3%, for the US, 73.3%, and for Japan, 60.3%. (12) Debt refers to loans. End of year data. (12) European definition also for the United States and Japan. (13) Net lending (+) / net borrowing (-) taken from the capital account. The figure for the euro area includes the proceeds from the sale of UMTS licenses. (14) End of year data compiled following Maastricht debt concepts and definitions. General government debt consists of deposits, securities other than shares and loans outstanding at nominal value and consolidated within the general government sector. (15-17) Balance of payments statistics; extra-euro area transactions only for the euro area. Inflows (+); outflows (-). (18) Occurrence dates indicated by {}'s.

Table 2—Markov-Switching Results (*m*=2) , 1970:1-2001:4

	US		Japan	Euro Area
	A: σ	B: $\sigma(s_t)$		
μ_1	-0.2571 (0.2438)	0.7167 (0.2653)	-0.3353 (1.0155)	-0.6981 (0.2368)
μ_2	1.0269 (0.1587)	0.7698 (0.1328)	0.7751 (0.3407)	0.7084 (0.1586)
ϕ_1	0.0495 (0.1028)	0.3300 (0.0898)	0.1288 (0.0706)	0.3432 (0.0819)
ϕ_2	/	/	0.1187 (0.0695)	0.2563 (0.0798)
ϕ_3	/	/	0.4031 (0.0780)	/
σ	$[0.71267]$	$\begin{bmatrix}1.1574\\0.50936\end{bmatrix}$	$\begin{bmatrix}2.1672\\0.7257\end{bmatrix}$	$[0.40939]$
P	$\begin{bmatrix}0.7608 & 0.2392\\0.0635 & 0.9365\end{bmatrix}$	$\begin{bmatrix}0.9819 & 0.0181\\5.723e-11 & 1.0000\end{bmatrix}$	$\begin{bmatrix}1.535e-8 & 1.000\\0.05273 & 0.9473\end{bmatrix}$	$\begin{bmatrix}0.4648 & 0.5352\\0.0564 & 0.9436\end{bmatrix}$
D (a)	$\begin{bmatrix}4.18\\15.75\end{bmatrix}$	$\begin{bmatrix}55.21\\/\end{bmatrix}$	$\begin{bmatrix}1.00\\18.96\end{bmatrix}$	$\begin{bmatrix}1.87\\17.72\end{bmatrix}$
ξ (b)	$\begin{bmatrix}0.2098\\0.7902\end{bmatrix}$	$\begin{bmatrix}0.43\\0.57\end{bmatrix}$	$\begin{bmatrix}0.0501\\0.9499\end{bmatrix}$	$\begin{bmatrix}0.0954\\0.9046\end{bmatrix}$
Log Likelihood	-155.0685	-141.7746	-152.6063	-93.8343
$\mu_1 = \mu_2$	/	0.0400 [0.8415]	/	/
$\sigma_1 = \sigma_2$	/	26.5875 [0.0000]	5.3282 [0.0210]	0.1500 [0.6985]

Notes: Standard errors in ()'s, probability-values in []s. / = Not applicable. (a) Duration of i^{th} state: $D_i = \frac{1}{1-\rho_{ii}}$. (b) Proportion of time in i^{th} state: $\xi_i = \frac{n_i}{T}, \sum_{i=1}^{m} \xi_i = 1$ where *T*=sample size, n_i = number of observations in i^{th} state.

Table 3–Asymmetry Tests

	US		Japan	Euro Area
	A: σ	B: $\sigma(s_t)$		
Expansions / Contractions	3.7680		18.9600	9.4759
Non Sharpness [(a)]	3.5113 [0.0610]	196.8677 [0.0000]	0.0006 [0.9801]	14.6451 [0.0001]
Deepness [(a)]	3.0545 [0.0805]	0.0044 [0.9469]	0.2032 [0.6522]	5.6733 [0.0172]
	Data Asymmetries			
Skewness	-0.1843 [0.4019]		-0.8925 [0.0000]	-0.51491 [0.0192]
Kurtosis	1.4562 [0.0011]		3.1563 [0.0000]	0.67791 [0.1293]
Normality (Jarque-Bera)	11.9411 [0.0025]		69.57924 [0.0000]	8.0437 [0.0179]

Note: (a) The asymmetry tests – discussed in Sichel (1993), Belaire-Franch and Contreras (2003) and Clements and Krolzig (2003) – are distributed as $\chi^2(1)$ under the null.

Table 4—Markov-Switching Results (*m*=3), 1970:1-2001:4

	US	Japan	Euro Area
μ_1	-0.2763 (0.1659)	-2.6415 (0.7066)	-0.6605 (0.1795)
μ_2	0.8591 (0.0965)	0.6744 (0.2893)	0.5521 (0.1109)
μ_3	1.8667 (0.2045)	1.2923 (0.6526)	1.2469 (0.1495)
ϕ_1	-0.2174 (0.1044)	0.1226 (0.0794)	0.2581 (0.0702)
ϕ_2	/	0.1074 (0.0746)	0.2078 (0.0658)
ϕ_3	/	0.3459 (0.0747)	/
σ	$[0.57438]$	$[0.76233]$	$[0.36031]$
P	$\begin{bmatrix} 0.7828 & 0.0563 & 0.1610 \\ 0.0589 & 0.9117 & 0.0294 \\ 0.1032 & 0.2511 & 0.6457 \end{bmatrix}$	$\begin{bmatrix} 4.531e-14 & 1.000 & 2.177e-7 \\ 7.092e-10 & 0.9856 & 0.01445 \\ 0.1277 & 2.119e-5 & 0.8723 \end{bmatrix}$	$\begin{bmatrix} 0.3731 & 0.2378 & 0.3891 \\ 0.07801 & 0.9220 & 1.844e-7 \\ 8.554e-6 & 0.1672 & 0.8328 \end{bmatrix}$
D	$\begin{bmatrix} 4.60 \\ 11.32 \\ 2.82 \end{bmatrix}$	$\begin{bmatrix} 1.00 \\ 69.21 \\ 7.83 \end{bmatrix}$	$\begin{bmatrix} 1.60 \\ 12.82 \\ 5.98 \end{bmatrix}$
ξ	$\begin{bmatrix} 0.2388 \\ 0.6027 \\ 0.1585 \end{bmatrix}$	$\begin{bmatrix} 0.0128 \\ 0.8868 \\ 0.1003 \end{bmatrix}$	$\begin{bmatrix} 0.0880 \\ 0.7072 \\ 0.2048 \end{bmatrix}$
Log Likelihood	-150.1998	-153.3527	-89.1092
$\mu_2 = \mu_3$	9.737 [0.0077]	3.8346 [0.1470]	9.4502 [0.0089]

Notes: See Notes to table 2.

Table 5—Business-Cycle Turning Points

	US				Japan				Euro area			
	Harding-Pagan	Two-Quarters	Markov switching		Harding-Pagan	Two-Quarters	Markov switching		Harding-Pagan	Two-Quarters	Markov switching	
			$m=2$(1)	$m=3$			$m=2$	$m=3$			$m=2$	$m=3$
Trough	1970:4*		1970:4*	1970:4*							1971:1	1971:1
Peak	**1973:4***	**1974:2**	**1973:4***	**1973:2**			**1973:4**	**1973:4**				
Trough	1975:1*	1975:1*	1975:1*	1975:2			1974:1	1974:1				
Peak									**1974:3**	**1974:3**	**1974:3**	**1974:3**
Trough									1975:1	1975:1	1975:1	1975:1
Peak	**1980:1***	**1980:1***	**1979:4**	**1979:4**					**1980:1**	**1980:1**		**1980:1**
Trough	1980:3*	1980:3*	1980:3*	1980:3*					1980:3	1980:3		1980:2
Peak			**1981:1**	**1981:1**								
Trough			1981:2									
Peak	**1981:3***	**1981:3***	**1981:3***									
Trough	1982:3	1982:1	1982:4*	1982:4*								
Peak											**1984:1**	**1984:1**
Trough											1984:2	1984:2
Peak											**1985:4**	**1985:4**
Trough											1986:1	1986:1
Peak	**1990:2**	**1990:2**	**1990:2**	**1990:2**			**1989:1**				**1986:3**	**1986:4**
Trough	1991:1*	1991:1*	1991:1*	1991:1*			1989:2				1987:1	1987:1
Peak												
Trough												
Peak									**1992:1**	**1992:1**	**1992:1**	**1992:1**
Trough									1993:1	1993:1	1993:1	1993:1
Peak					**1993:1**	**1993:1**						
Trough					1993:4	1993:4						
Peak												
Trough												
Peak							**1997:1**	**1997:1**				
Trough							1997:2	1997:2				
Peak					**1997:4**	**1997:4**						
Trough					1998:2	1998:2						
Peak	**2000:4**	**2000:4**	**2000:3**	**2000:3**								
Trough	2001:3*	2001:3*	2001:3*	2001:4								
Peak					**2001:1**	**2001:1**						
Trough						2001:4						

Notes: (1) Results refers to model A in Table 2. A * indicates *NBER* business cycle reference dates.

Table 6—Cycle Synchronization

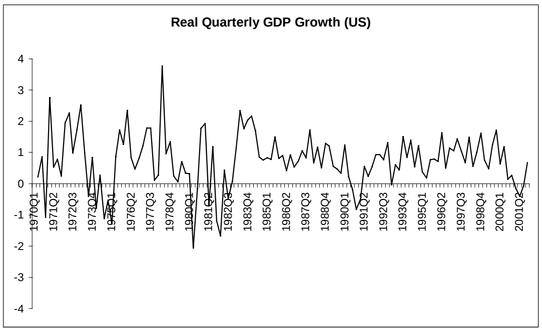
	US	Japan	Euro area
Common Phase Coefficient [a]			
US	1		
Japan	0.81	1	
Euro Area	0.87*	0.84	1
Common Phase Coefficient (Standardized)			
US	1		
Japan	0.26	1	
Euro Area	2.30	-0.68	1
Cross-Correlation of Smoothed Probabilities, *m*=3: Low (Moderate) {High} Growth [b]			
US	1		
Japan	0.100 (0.118) {0.263*}	1	
Euro Area	0.046 (0.070) {0.270*}	-0.045 (0.320*) {0.477*}	1

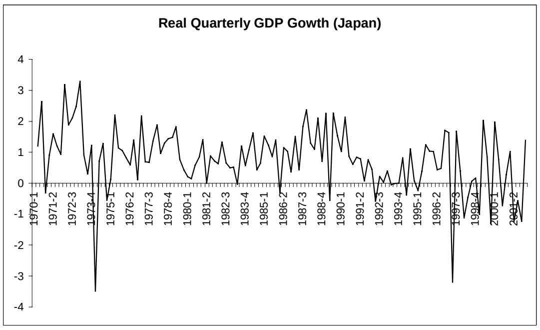
Notes:

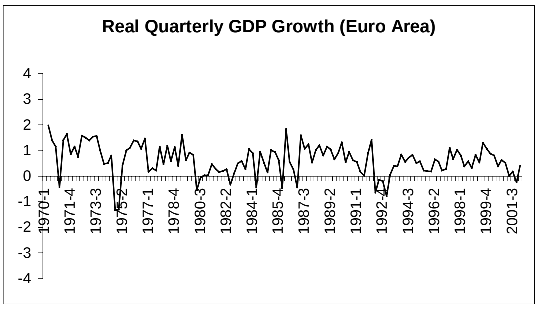
(a) An * denotes significance at the 5% level using the response surface parameters of McDermott and Scott (2000).

(b) An * denotes significance at the one-sided 2.5% level based on a *Fisher's z-transformation* of the correlation coefficient.

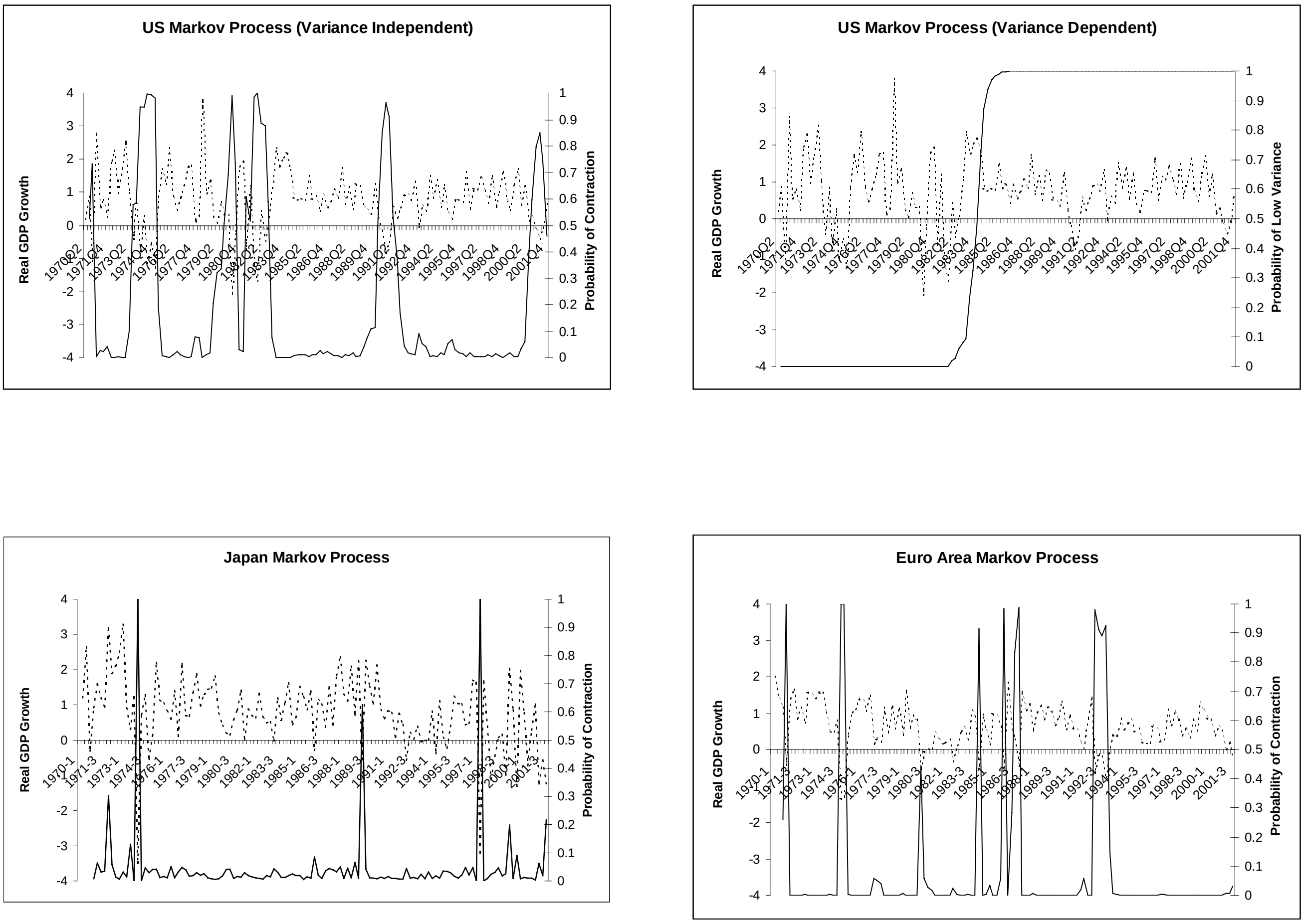
Graphs 1—GDP Growth





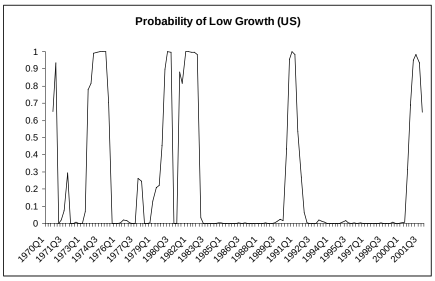


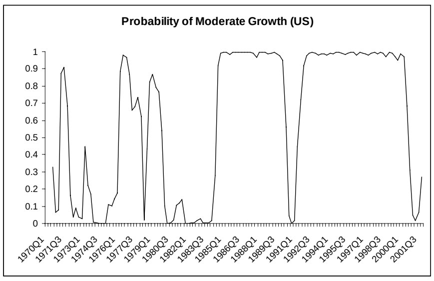
Graphs 2—Markov-Switching Characteristics (*m*=2)

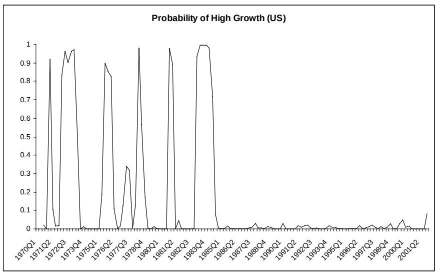


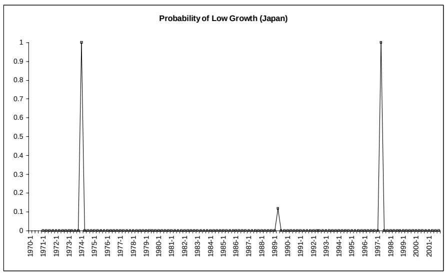
Note: Graphs show the growth series (rhs scale) and smoothed probabilities (lhs).

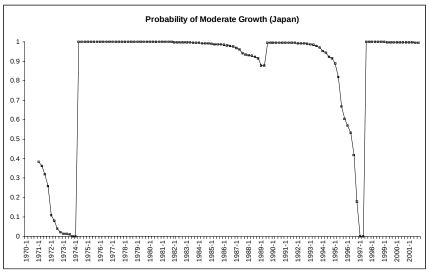
Graphs 3—Markov-Switching Characteristics (*m*=3)

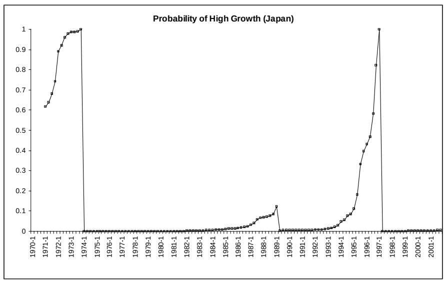


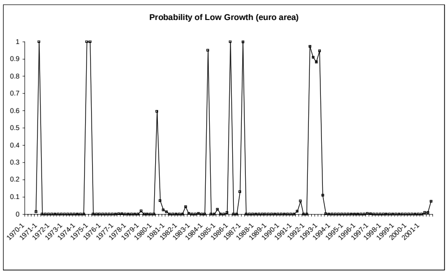


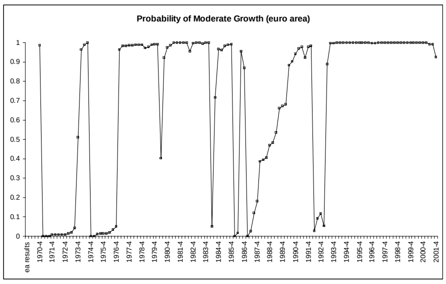


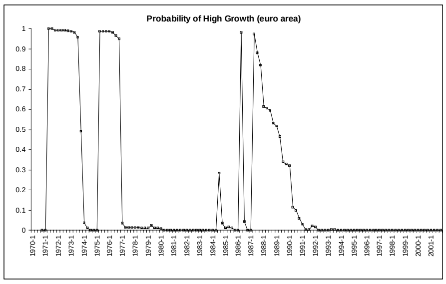




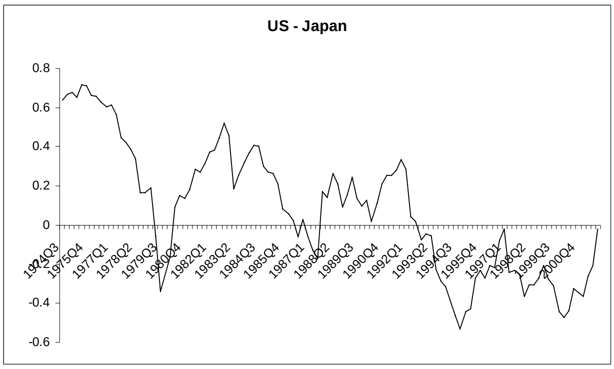


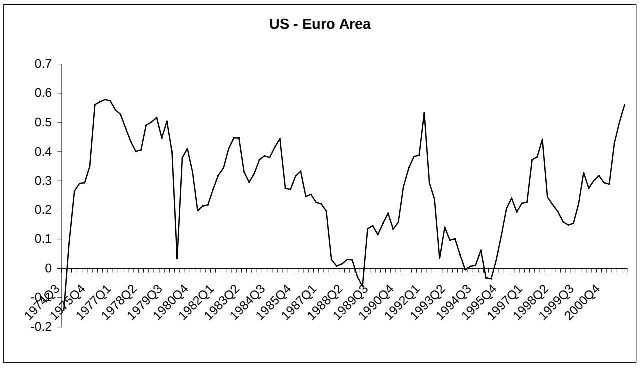


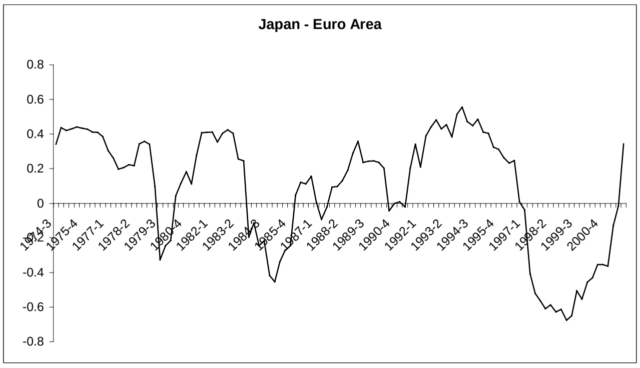




Graphs 4—Rolling Cross-Correlations







Note: Correlations derived at rolling 5-year windows.

Appendix

Previously we considered MS models where the regime change affected mean and variance in an equivalent manner. Here we consider the case where variance and means can break independently of one another (an "augmented" model):

$$\Delta y_t = \mu(s_t, v_t) + \sum_{i=1}^{q} \phi_i \left[\Delta y_{t-i} - \mu(s_{t-i}, v_{t-i})\right] + \varepsilon_t \qquad (1A)$$

where v indicates the variance state and s is as before. The model is similar to that of equation (1) except that specification (1A) yields two possible states for the variance, with σ_1^2 (σ_2^2) being the variance in the high-variance (low-variance) state. Furthermore, we thus have four possible state means – e.g., μ_{11} for s_t=1, v_t=1 and μ_{21} for s_t=2, v_t=1 etc (i.e., μ_{11} denotes mean growth in the expansionary, high-variance regime).

Table 1A gives the state-dependent results and **Graphs 1A** plots growth alongside the associated smoothed probabilities. Note these are only presented for the US and Japan, since there is no evidence of regime-dependent variances for the euro area. Overall, the results appear economically reasonable – with the means across the various regimes statistically well identified and the smoothed probabilities corresponding well to viable turning points and/or periods of volatility changes. For neither country, though, do we find a point estimate such that μ_{22}<0.

For the US, we again find the marked reduction in output volatility from 1984:1. There is essentially little difference between the earlier smoothed probabilities and turning points compared to Graphs 2A – except that the business cycle turning points and the variance change are now explicitly separated. Furthermore, this specification – like that of the three-state case – also predicts a full probability of contraction near the end of the sample.

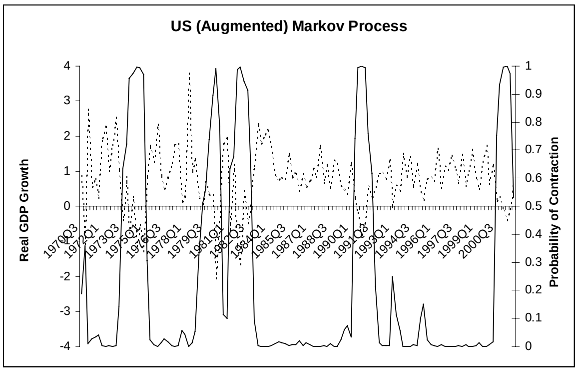
For Japan, notably, we identify two high volatility states: from 1970-1975:1 and from 1997:1-2001:4. Interestingly, these reflect quite different factors. The first is associated with the rapid growth of the 1970s whilst the latter reflect the late 1990s deflation. The probabilities associated with the growth process (the 1st panel, second row in Graphs 1A) shows that cycle from the early 1990s Japan is considered to be, if not in contraction, certainly in a period of chronically low growth. Finally, however, the low growth means (like the pervious two-state case) do not appear to match the downturn witnessed in the data.

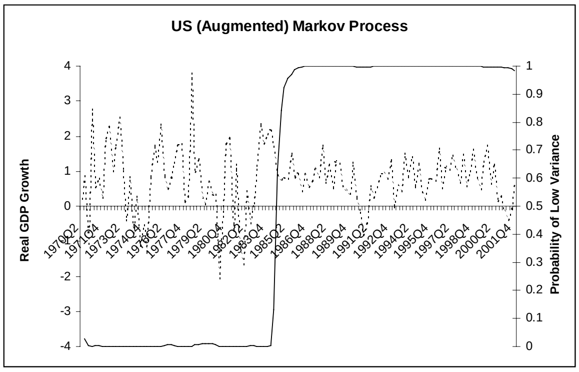
Table 1A—Markov-Switching Results

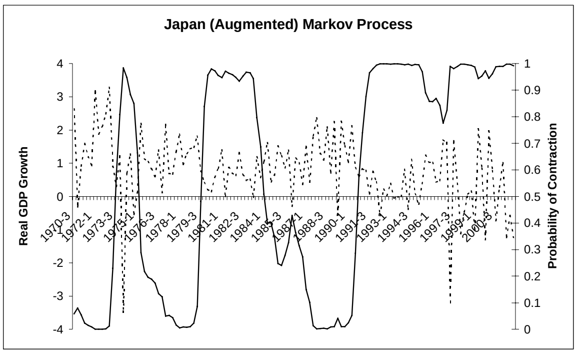
	US		Japan (1)	
	High Variance State	Low Variance State	High Variance State	Low Variance State
μ_1	1.2778 (0.1792)	0.9006 (0.0550)	1.5522 (0.3557)	1.2046 (0.1367)
μ_2	-0.33461 (0.2937)	0.0031 (0.1436)	-0.0607 (0.2531)	0.5646 (0.1158)
ϕ_1	-0.0632 (0.1057)		-0.1573 (0.0988)	
σ	$\begin{bmatrix}0.9264 & 0.4032\end{bmatrix}$		$\begin{bmatrix}1.2478 & 0.5931\end{bmatrix}$	
P	$\begin{bmatrix}0.9370 & 0.0630 \\ 0.1984 & 0.8016\end{bmatrix}$	$\begin{bmatrix}0.9896 & 0.0103 \\ 0.0095 & 0.9904\end{bmatrix}$	$\begin{bmatrix}0.9280 & 0.0720 \\ 0.0533 & 0.9467\end{bmatrix}$	$\begin{bmatrix}0.9831 & 0.0169 \\ 0.0195 & 0.9805\end{bmatrix}$
Log Likelihood	-137.48282		-161.5948	
$\mu_1 = \mu_2$	3.4096 [0.0003]	4.5190 [0.0000]	2.6493 [0.0040]	2.5347 [0.0113]

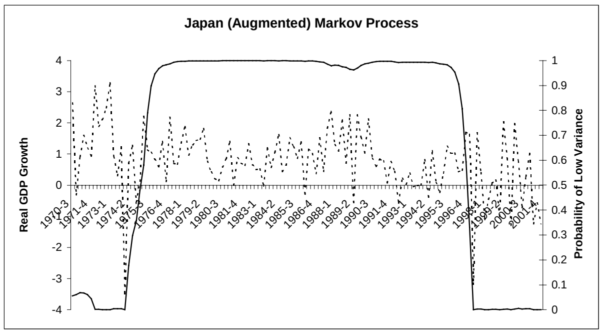
Note:
(1) In the variance and mean break model only one lag was significant for Japan.

Graphs 1A—Markov-Switching Characteristics with independent variance and means breaks.









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