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International Business Cycles: Detection and Properties

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Abstract
After conceptual clarification of "international business cycle" and a review of the literature, a new indicator is proposed. This indicator refers to two time series only and allows for an internationally comparable quantification of a country's position in the business cycle. We then calculate times series of this indicator from 1970 to 2000 for 30 countries. After some plausibility checks, we refer to these series to test a number of hypotheses. Cross correlations reveal a high degree of interconnectedness. Moreover, the number of highly positive correlations increased over time, whereas the number of low and moderate correlations decreased. A principal component analysis yields a first component that can be interpreted as the world business cycle. The further components suggest a Scandinavian/Anglo-Saxon business cycle as well as another, smaller group of Anglo-Saxon countries that move together. This finding is replicated by a hierarchical cluster analysis, which in addition suggests a closely integrated group of non-Scandinavian and non-English speaking European countries plus Japan and Israel. Furthermore, there is indication for some, albeit weak business cycle integration in Southeast Asia and in South America. The international business cycle is thus found to have a hierarchical structure.

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1 Introduction

The identification of a country's cyclical position is of vital importance for economic policy. However, as the business cycle is not directly observable, in practice, one has to resort to more or less directly observable determinants or indicators. In a globalised world, in addition to domestic factors, international business cycles may play an important role.

This paper will first discuss concepts, definitions and theoretical explanations for international business cycles. This is followed by an overview of previous empirical studies. We then suggest an approximation of economy-wide capacity utilisation, which draws on two yearly time series– GDP and the gross investment rate – only. We then demonstrate that this measure provides a parsimonious, yet reliable and valid as well as internationally perfectly comparable determination of a country's economic position in the business cycle that compares favourably with the output gap, i.e. the standard variable economy-wide capacity utilisation. Finally, based on the time series of our proposed measure in a panel of 30 countries from 1970 to 2000, we test a number of hypotheses regarding the characteristics of international business cycles.

International business cycles: concepts and definitions

The concepts of international business cycles or a world business cycle[1] have long captured the imagination of economists. In either case, the cycle is affecting more than a single country. In a fully integrated world economy, we might find a dominant world business cycle with no pronounced regional variation, whereas in a less than fully integrated world, some of the trans-national cyclical co-movement will be confined to geographical regions or economic blocks.

The economic history of the last decades records an increase in economic openness. Typically, however, we do not see countries unambiguously opening their economies towards the rest of the world.[2] Rather, we see some removal of international barriers to economic activity going hand-in-hand with the consolidation of supra-national economic blocks that tear down borders within but at the same time erect new barriers vis-à-vis the rest of the world. Hence, the typical pattern of economic globalisation is currently the formation of blocks, resulting in a polycentric and possibly hierarchical structure. Accordingly, a reasonable assumption is that, presently, different layers of business cycles proceed at the same time. Formally, this structure can be represented as a polycentric hierarchy of cycles, where the cyclical position of country i at time t $P_{i,t}$ is determined by country-specific ("idiosyncratic") factors $I_{i,t}$, supra-national developments $S_{j,t}$, business conditions within structurally defined groups of countries $G_{k,t}$, and a world business cycle W_t, so that

$$P_{i,t} = f(I_{i,t}, S_{j,t}, G_{k,t}, W_t).$$

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1 For a discussion of the world business cycle, see *Gregory et al.* (1997).

2 For a stylised economic history from a trade and openness perspective, see *Bergsten* (2001).

Note that this notation immediately suggests factor or principal component analysis as a method to address this concept empirically. In particular, the observed variable – $P_{i,t}$ – could be explained by a number of non-measurable latent variables that reflect the hierarchy of cycles. And indeed, a number of recent studies on international business cycles have referred to factor models. Before we turn to this research, we shall briefly summarise some fundamental theoretical considerations on international business cycles.

2 Theoretical considerations on international business cycles

Traditionally, the cyclicality of economic conditions in the secondary and tertiary sector is referred to an investment cycle, where at some stage over-investment leads to more or less severe corrections until a new boom sets in. The underlying assumption is that a considerable number of market participants are reacting to the same signals. These may be the employment outlook, profits, order books, raw material and intermediate goods prices, inventories, exchange rates, demand for exports or news about international crises and war or peace. Apart from this view, academic economists typically highlight the "real business cycle" theory.[3] Based on the assumption of rational and informed agents, this theory sees the origin of cycles in exogenous shocks (technical innovation or political intervention). Moreover, though it certainly does not represent the mainstream, some economists continue to refer to Schumpeter's theory of the business cycle (*Schumpeter* 1939). This theory ascribes the business cycle to clusters of innovations which lead to a general phase of prosperity. New products and procedures deliver monopoly rents to the pioneers; on the other hand they make some of the inherited capital stock obsolete in economic terms. This "creative destruction" triggers vigorous price adjustments and consequently entrepreneurs and bankers face difficulty in assessing the profitability of further innovation and investment. Moreover, at that stage, a considerable part of investment is getting speculative rather than innovative. Once the initial cluster of innovations has diffused through the economy, profits converge towards zero. The boom is over and the economy returns to a stationary state. This may even manifest itself as a depression. Typically, however, the price adjustment that happened through the recession forms the basis for new innovative activity which again culminates in a cluster of innovations. Evidence for this business cycle theory so far is sparse. Yet, it cannot be ruled out that the "Second Industrial Revolution" (within the IT sector) has brought about a convergence of technological trajectories, which would result in a clustering of innovations and hence constitute the basis for a next Schumpeter cycle.

These theories comprise a number of arguments that can likewise serve as theoretical explanations for *supra-nationality* of business cycles. Generally, a systematic commonality of economic activity across different territorial units has to be attributed to cyclical forces operating across regions.[4] These could affect either prices or quantities or both, and relate to goods and services, factors of production, financial securities or to psychological factors such as consumer confidence or the "animal spirits" of entrepreneurs. Hence, as far as economic agents react to signals

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3 See *Lucke* (2002).

4 See, amongst others, *Clark and Van Wincoop* (2001) and *Artis* (2003).

from abroad, we would expect to find trans-nationality in business cycles. Real business cycle theory directly implies that the business cycle will be supra-national if this is true for the driving forces, i.e. the technology and policy shocks that are hitting the international economy.[5] From a Schumpeterian perspective, a common technological trajectory would constitute the basis for supra-nationality of the business cycle.[6]

Economic theory hence states a number of plausible arguments for the emergence of international business cycles and identifies potentially triggering factors as well as likely channels for international transmission and diffusion. Some of the factors that drive the business cycle operate predominantly domestically, while others have more international significance. In this context, we would expect that countries are not likewise affected by factors that drive international cycles. Geographic, cultural and technological proximity would imply more similar reactions to impulses from the international economy. Moreover, "cyclical proximity" is affected by economic and political integration (or disintegration) and thus not time invariant.

The economic integration of Europe may serve as an illustration of these considerations, as it has shaped or at least deepened a distinctive European business cycle.[7] The cyclical integration is nevertheless far from complete. In particular, private consumption is still heavily affected by country specific idiosyncrasies.[8] Furthermore, according to recent findings, it appears that the overall deepening of cyclical integration in the EC/EU has started to flatten out.[9] Intra-European frontiers hence continue – to some extent – to be boundaries for the business cycle.[10]

At this stage, we can conclude that business cycles are nowadays a more or less international phenomenon. From a global perspective, the cyclicity of economic activity can analytically be decomposed into local, regional,[11] industry specific, national and supra-national cycles and – possibly – a global cycle. The empirical studies on international business cycles that we are going to survey in the following section will provide additional evidence for this view.

3 Previous research on international business cycles

So far, most attempts to identify international business cycles have – at least implicitly – referred to the classical NBER concept of *Burns and Mitchell* (1946), which defines the business cycle as a co-movement of a number of economic parameters and aggregates. For example, *Vahid and Engle* (1993) and *Cubadda* (1999) show that business cycles can be modelled econometrically by

5 *Norrbin and Schlagenhauf* (1996) find "limited support" for real business cycles in form of industry specific cycles with international business cycles. *Imbs* (1999) shows that OECD countries with similar industrial specializations are characterised by distinctive co-movement of economic activity.

6 This might especially affect groups of countries with a similar human capital endowment, allowing for a quick diffusion of clusters of innovations; see *Comin and Hobijn* (2004).

7 See *Fatás* (1997).

8 See *Ambler et al.* (2004).

9 See *Artis* (2003).

10 See *Clark and van Wincoop* (2001).

11 The regional level *within* a country will not be subjected to an analysis in this paper. For advances in this direction, see *Belke and Heine* (2004) as well as *Tondl and Traistaru-Siedschlag* (2006).

"common feature" and "co-dependence" analyses (both based on cointegration) as a joint movement of the cyclical components of income and consumption. Some widely cited studies specify international business cycles as dynamic factor models, where a multi-dimensional variable space of economic time series across a sample of countries is reduced to a limited number of dimensions.[12] The results of this approach are promising. It has been demonstrated that factor models are sufficiently general to identify characteristic cyclical movement patterns of a large number of variables in the first factor. Studies that consider larger numbers of countries normally find a polycentric or hierarchical structure. Moreover, the empirical literature suggests that there may be a global factor that is mainly driven by shocks, along with cyclical movements of more confined nature.[13]

Amongst analyses referring to dynamic factor models, the work of *Kose et al.* (2003) has to be highlighted. These authors subject yearly time series of output, consumption and investment from 1960 to 1990 across 60 countries, taken from the Penn World Tables,[14] to a dynamic factor analysis and identify a world factor as well as factors for North America, Europe, Oceania, Latin America, Africa, Asia (rich) as well as Asia (poor). This study is remarkable as it refers to a comparably broad country sample,[15] so that – unlike in other studies – the multi-layer structure of business cycles that becomes visible in this analysis draws a more convincing picture of the world business cycle than studies that rely on smaller country samples. *Kose et alii's* central result is that there indeed is a world cycle that accounts for a considerable share of output fluctuation. Moreover, co-movement is more pronounced within the group of developed countries, indicating that the international transmission of the world business cycle to the poorer parts of the word is less effective, which is an intuitively persuasive structural finding, given that these countries are less integrated into the world economy. On the other hand, apart from a North American factor (covering the NAFTA countries) supra-national factors emerge far less important than in previous studies. Furthermore, compared to output, consumption and investment are governed more by country specific factors. Finally, the analysis confirms a hierarchy with the world factor accounting for the bulk of the lowest frequencies, whereas the subsequent factors tend to explain the higher frequencies of the underlying series.

Notwithstanding these encouraging findings, a severe disadvantage of dynamic factor analysis in practical terms is its requirement regarding the completeness and consistency of the data, and the econometric effort is remarkable. The empirical literature on international business cycles thus still refers to less complex methods, and the resulting findings are sometimes no less revealing. *Christodoulakis et al.* (1995) for example, screen HP-filtered quarterly series from EC coun-

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[12] See e.g. *Norrbin and Schlagenhauf* (1996), *Gregory et al.* (1997), *Forni et al.* (2001), *Kose et al*. (2003) and *Marcellino et al.* (2003). Dynamic factor models are, of course, also suitable for the identification of NBER type business cycles within *one* country or *one* region, see e.g. *Stock and Watson* (1999), *Bandholz and Funke* (2003) and *Mariano and Murasawa* (2003).

[13] See *Malek Mansour* (2003).

[14] For a description of this data set, see *Summers and Heston* (1988).

[15] The extension of the usual sample size of around 20 countries to 60 comes at a price: *Kose et al*. (2003) analyse yearly instead of the usual quarterly series, and the quality of the data quoted in the Penn World Tables is occasionally rather doubtful (see Section 4.1 of this paper).

tries for cross correlations and find close co-movements of output growth, from which they conclude that these countries constitute a distinctive international business cycle. *Ambler at al.* (2004) run pairwise cross correlations of different macroeconomic indicators for a number of developed countries and find plenty of positive, albeit usually only weak to moderate correlations. Interestingly, the private consumption cycles again show hardly any sign of international integration. Based on a time varying weighting matrix which is derived from the "stylised facts" of national and international business cycles, *Lumsdaine and Prasad* (2003) identify a European and a world business cycle factor.

A few studies refer to standard (cross sectional) rather than dynamic factor or principal component analyses. Though they do not model the time dimension, a significant advantage in practical terms is that they require only one variable (a time series reflecting the cycle) per country. The points on the time axis are then treated as observations. Accordingly, countries that exhibit a similar cycle tend to "load" (correlate) on the same factors or principal components. An early application of this method is a study by *Fuhrmann* (1980). However, it comprises only three countries. More recently, *Sayek and Selover* (2002) conduct a principal component analysis of GDP growth rates of five European countries as well as the US and obtain two principal components with eigenvalues greater than one. They interpret this as a reflection of general factor as well as two supra-national cycles with opposite phases, one of them comprising Germany and France and the other the UK and the US. *Bezmen and Selover* (2005) conduct a comparable analysis for a number of Latin American countries, the EU, Japan and the US. Their results point to a comparably low degree of cyclical integration within Latin America. Yet another approach that builds on principal component analysis is suggested by *Holmes* (2002). This study assesses business cycles convergence towards Germany by examining stationarity of a first principal component of deviations of a number of EU countries' cycles from the German cycle, which is an elegant way to specify a centre-periphery model empirically. *Holmes* finds strong convergence towards the German cycle during the 1990s for Belgium, France and the Netherlands.

Yet another statistical method that has proven useful for the identification of international business cycles is cluster analysis. For a sample of OECD countries, *Artis and Zhang* (2001) by means of hierarchical cluster analysis identify a group of Central European countries (Germany, France, Netherlands, Belgium and Austria), a predominantly Nordic periphery group (Denmark, Ireland, UK, Switzerland, Sweden, Norway and Finland), a southern periphery group (Italy, Spain, Portugal and Greece), a North American group (the US and Canada) as well as Japan as an cyclically isolated economy. A study by *Artis* (2003), covering an enlarged sample of OECD countries, constructs a dissimilarity measure based on cross correlations of GDP growth rates and subjects it to a hierarchical cluster analysis. As in *Artis and Zhang* (2001), the country groups that form clusters are similar, albeit not identical to the countries that constitute the major supra-national economic regions or blocks. *Boreiko* (2003) refers to "fuzzy cluster analysis" – an algorithm allowing for more ambiguity than hierarchical clustering – to evaluate convergence of Eastern European transition economies with the EMU member countries. He finds that Estonia and Slovenia are "leaders" in convergence, which is in part attributed to "business cycles correlation", in other words, to their accession to an international business cycle that is dominated by EMU member countries.

To sum up this section, we can conclude that the empirical evidence generally confirms the theoretical expectation of a hierarchical and to some degree polycentric structure of international business cycles. Yet, in detail, there is little congruence as far as the identification of countries that constitute particular international cycles is concerned. Most likely, apart from the large variety of methods applied, this has to be attributed to the diversity as well as to the typically small size of the country samples that these studies refer to.

4 An empirical analysis based of the capital coefficient

As we have seen, international business cycles have been analysed with a range of strikingly diverse methods. Presently, dynamic factor analysis tends to dominant the field. Cross correlation analysis is also regularly applied. Principal component analysis and cluster analysis are used occasionally, but as they do not belong to the standard tools of econometrics, they are not the preferred methods.

The advantages and disadvantages of the different methods are rooted in their appropriateness to reflect the theoretical concept of international business cycles. Yet, in practical terms, requirements concerning the data regularly impair their appliility.

Dynamic factor as well as common feature- and co-dependence analyses are theoretically well defined implementations of the NBER concept (business cycles as a synchronism of a large number of economic series). Yet, unless the analysis is restricted to few countries with a sound statistical basis, data availability erects high barriers for their implementation.

In contrast to this, a univariate characterisation of the cyclical movement allows to extend the empirical analyses to a significantly larger number of countries, which is clearly desirable when the aim is to identify a truly global structure. An international correlation matrix can for example help to identify international cyclical integration. Cross correlations allow for the consideration of phase shifts. The disadvantage of these methods is that the analysis is pairwise, so that it is not possible to determine a world business cycle or a hierarchy of cycles. For this purpose, data reduction algorithms like principal component analysis or factor analysis are appropriate methods. A first principal component (or factor) that correlates positively with a large number of country cycles can be interpreted as a world business cycle, whereas subsequent factors or principal components would suggest cycles comprising (geographically or structurally related) sub-groups of countries. To reveal a hierarchical structure, cluster analysis, grouping country cycles and successively combining them into bundles ("clusters") according to their degree of similarity, would be the preferred method. Accordingly, these methods are particularly suitable for our purpose. Yet, they require that the cyclical position of a country is adequately captured in a single time series.

In what follows, we shall try to proceed in this direction, referring to the capital coefficient, a variable that does not figure prominently in the recent literature on international cycles (or the business cycle in general), but which – as we shall demonstrate – is particularly suitable to reflect a country's cyclical position on the time axis.

4.1 A new indicator for cyclical development

Business cycles characteristically manifest themselves in over- or underutilisation of productive resources of an economy. Consequently, applied business cycle analysis regularly refers to variables reflecting the utilisation of the factors of production – labour and capital –, usually approximated by the unemployment rate and the rate of capital utilisation. Apart from this, variables like the output gap aim at quantifying aggregate economic capacity utilisation.

Labour and capital utilisation both consider just one factor of production and in doing so may give a distorted picture of the cyclical movement of an economy as a whole, unless labour and capital utilisation are co-moving. This, however, is usually not the case. Labour utilisation is typically *following* the business cycle, and furthermore, is it less cyclically responsive compared to capital utilisation. In addition to this, though at a first glance unemployment statistics seem to be a well-documented and readily available indicator of the business cycle, the data are almost hopeless for international and inter-temporal comparisons.

Capital utilisation is more convincing, since it typically proceeds simultaneously with the business cycle. Unfortunately, capital utilisation is not well documented statistical information.

From a theoretical perspective, the output gap $(Y_t - Y^*_t)/Y^*_t$, which is defined as the relative deviation of the observed output Y at time t from potential output Y^*, is probably the most convincing concept to determine the cyclical position of an economy. And indeed, it is widely used amongst theorists as well as practitioners. Unfortunately, for practical purposes, the concept depends on the determination of Y^*, which – like the business cycle – is an inherently unobservable variable. Ideally, a macroeconomic production function should quantify the potential output path Y^*_t. Since this is a formidable task, it is common to refer to univariate statistical procedures – filters – that are designed to isolate the trend of the Y_t series from the cycle (and the noise) and then to interpret this trend as Y^*_t. Various low pass filters are doing this job fairly well, and this statistical approach impresses through its simplicity. The assumption that the univariate output trend corresponds to potential output, however, suffers from the fact that it ignores all other information that could lead to a reassessment of the potential. Exogenous shocks or technological developments which lead to persistent level changes of the potential are ignored, as are changes to the stock of accumulated factors of production (physical and human capital) due to changes to the net investment ratios. This last point is particularly critical: while shocks to observed output – which are filtered out by the low pass filter – rightly appear as deviations from potential, technical change or evolution of the economy's capital stock are not duly considered when determining potential output with a low pass filter, which would identify them as cyclical.

To avoid this pitfall, if possible, information about the development of the production potential should be considered.[16] A straightforward step in this direction is to observe not only the de-

[16] A common way to amend the univariate low pass filter approach with additional information are so-called multivariate filters, which are used by a number of central banks, e.g. the Bank of Canada, the Reserve Bank of New Zealand and the Reserve Bank of Australia, to name just a few. For our purpose, unfortunately, we cannot refer to these output gap series, since each of them is individually tailored, which impairs international comparability.

velopment of Y_t but in addition that of the capital stock K_t, which is one of the decisive determinants of the potential output path.

Referring to a short term production function of type

$$Y_t = f(K_t)$$

the capital coefficient $v_t = (K/Y)_t$ is the only technology parameter. This suggests a modified approach to determine the cyclical position of a country, where we refer to the time series of the capital coefficient v_t rather than to the time series Y_t. In this way, we now capture those changes to potential that go back to changes in K. Yet, such a short term approach would rule out technical change, since only stationary technology would imply v to be constant. Realistically, we should allow for gradual changes to v_t.

This reasoning now leads us to specify our preferred measure of the business cycle: Based on a low pass filtered series of the capital coefficient, we interpret the trend v^*_t as an approximation of the evolution of technology f. Hence, the relative deviation of the trend capital coefficient from the observed capital coefficient reflects the degree of capital utilisation with an evolving technology v_t. Let us call this series capacity utilisation, where

$$CapU_t = (v^*_t - v_t)/v_t$$

Capacity utilisation $CapU_t$, like the output gap, fluctuates around zero and thus is stationary by construction. It is as easy to interpret as the output gap, but compared to the low pass filtered univariate output gap, it refers to twice the amount of information. Due to this reduction in informational inefficiency, it may be expected to be superior in reflecting the cyclical position of an economy.[17]

Country sample and data

As in other cross-country studies, we are faced with a *trade off* between quality and quantity of the data points that we can include in our analysis. Applied business cycle research regularly refers to monthly, quarterly and yearly data. For aggregates like GDP and investment, the frequency that is mostly refered to is quarterly, as monthly breakdowns are usually not available for national accounts. Moreover, monthly series are typically quite volatile due to noise and seasonality, so that it is difficult to detect a trend-cycle. Quarterly data need to be filtered too, but here it is predominantly the seasonal components that need to be identified, which is typically a manageable task. On the other hand, quarterly data often are of questionable quality.[18] They are normally obtained from a quarterly breakdown of yearly aggregates from national accounts data re-

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[17] Methods for the identification of the cyclical position of an economy based on the analysis of the observed capital coefficient are not a novelty; see e.g. *Phillips* (1963), *Klein and Preston* (1967), *Klein* (1969) and *Oppenländer* (1976). Yet, the output gap is nowadays the dominant business cycle indicator, so that our method suggests a revival of older and presently rarely used approaches. Compared to the prototypes from the 1960s and 1970s, our proposal is new in that v^* is extracted with a low pass filter, whereas the earlier approaches granted less flexibility and either acted on the assumption of a constant capital coefficient or modeled the capital coefficient as a linear trend.

[18] See *Agénor et al.* (2000).

lying on quarterly indicator series. The quarterly pattern, which is to some degree arbitrarily imposed on the yearly numbers, then accounts for a major share of the variance of a series. Yearly series do not suffer from these problems. On the other hand, yearly series typically do not offer the degrees of freedom that are required for sophisticated statistical analyses. Furthermore, with yearly data, it is not possible to track phase shifts that occur at a higher frequency, such as presumable most international transmission mechanisms of supra-national cyclicity.

For our purposes, we choose not to restrict our sample to countries with well-documented quarterly national accounts data, but rather to work with yearly series.[19] For this frequency, two international data bases are usually referred to: the Penn World Tables, which report years from 1950, and the World Bank's World Development Indicators, reporting data from 1970. Hence, due to the length of the time series that can be drawn from theses sources, the Penn World Tables appear to be the first choice. However, as it has recently become apparent that the Penn World Tables are plagued be a number of obvious inconsistencies,[20] we shall mainly refer to the World Development Indicators. Yet, we use the Penn World Tables for the construction of splined time series of Y_t and $(K/Y)_t$ that comprise the years 1950–2004,[21] where the data points from 1950 to 1969 are based on the Penn World Tables and referred to for two auxiliary procedures: (1) calculation of the capital stock in 1969 and (2) low pass filtering of Y_t and $(K/Y)_t$ at the left margin. For the following steps, we then refer to data points from 1970 onward only.

To ensure that a minimum standard of data quality is met, the cross-sectional coverage of our sample comprises those 30 countries, which the Penn World Tables classify as belonging to the first two (A and B) of five categories in a data quality ranking.[22] With Argentina, Chile and Uruguay as well as Hong Kong, Singapore and South Korea, the country sample also comprises some South American and Asian emerging countries, so that our study will not be restricted to devel-

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[19] Although quarterly data are preferred when analysing international business cycles, reference to yearly data is not unusual; see e.g. *Kose et al*., *Sayek and Selover* (2002) as well as *Bezmen and Selover* (2005).

[20] As *Dowrick* (2005) shows, the inconsistencies can partly be ascribed to serious mistakes in the demographic data. Obviously, there are also problems with the deflators of high inflation countries.

[21] From the World Development Indicators online data base we take, or calculate, respectively, the following series: GDP Y, in local currency units, deflated ("real GDP, constant local currency units") as well as the gross investment rate I/Y ("gross capital formation/GDP, current local currency units"). From the Penn World Tables we take, or calculate, respectively, the conceptually comparable series: GDP Y in US-dollar, deflated, which is obtained by the multiplication of Y/P by P as well as by the purchasing power parity adjusted price level (real GDP per capita, chain index, "RGDPCH", population "POP" and price level of GDP "P"), the gross investment rate I/Y (share of real GDP "CI"). From the two series for Y we calculate index series that are set equal to one for the year 1990, so that differences in levels are eliminated. We than calculate data points not covered by the World Development Indicators as $X_t = X(PWT)_t \times X(WDI)_u / X(PWT)_u$, where *PWT* and *WDI* refer to the Penn World Tables and the World Development Indicators, respectively, and where u denotes the first year for which entries for X appear in both sources. The correlation between the series from the two sources are significant and high (on average 0.91 for Y and 0.80 for I/Y), so that they can be considered as suitable predictors for each other.

[22] These are: Argentina, Australia, Austria, Belgium, Canada, Chile, Denmark, Finland, France, Germany, the UK, Greece, Hong Kong, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Netherlands, New Zealand, Norway, Portugal, Singapore, South Korea, Spain, Sweden, Switzerland, Uruguay and the US.

oped countries. With the exception of Africa all continents are represented,[23] so that – if there is any – a world business cycle should show up in our analyses.[24]

Calculation of the physical capital stock time series

Internationally comparable information regarding the physical capital stock K is sparse.[25] We shall hence estimate capital stock time series for the countries in our sample. This is carried out with the "perpetual inventory" method,[26] which draws on the identity of the capital stock in period t K_t with the capital stock of the preceding period K_{t-1} minus depreciation δK_{t-1} plus gross investment I_{t-1}, so that

$$K_t = K_{t-1} (1 - \delta_{t-1}) + I_{t-1}.$$

This, however, still leaves the capital stock in the base period K_0 to be determined, along with the depreciation rate. A transparent method for estimation of capital stock in a base year that relies on few assumptions was suggested by *Harberger* (1978). Starting from the identity of gross investment with depreciation δK plus net investment gK (where g denotes the growth rate of the capital stock), it holds by definition that

$$I = \delta K + g K = (\delta + w) K.$$

Thus, the capital stock in the base year can be written as

$$K_0 = I_0/(\delta_0 + g_0).$$

Harberger suggests to determinate I_0 by averaging the first three observations for gross investment, thereby smoothing the empirical fluctuations. Still, the depreciation rate δ_0 and the growth rate of the capital stock g_0 remain unknown. Now, with the assumption, borrowed from neoclassical growth theory, that the capital coefficient is constant,[27] the growth rate of the capital stock in equilibrium equals the secular growth rate of GDP g^*. *Harberger* again suggests taking the three year average at the left margin of the series an estimate for g^*. We slightly modify the suggested procedure by referring to low pass filtered trends for the starting values rather than to the average of the first three observations. The trend reflects information from more than three

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23 The reason for this is pragmatic (required quality of data). Apart from this, it is questionable in how far Africa is integrated into the world business cycle. With a high share of agriculture in economic activity, as it is typical in most African countries, economic fluctuations primarily are a function of the states of nature (such as weather); see *Agénor et al*. (2000).

24 The latest vintages of the Penn World Tables report backcasts for all of Germany until 1970. For the years 1950–1969 we refer to the data for West Germany from an earlier version of the Penn World Tables (5.6) and link these with the later by calculating $X_t = X(old)_t \times (X(new)_{1970}/X(old)_{1970})$.

25 The last vintages of the Penn World Tables do no longer comprise capital stocks. Obviously, there is little faith in the previous estimates.

26 An overview about methods for capital stock estimations is given by *Dadkhan and Zahedi* (1990).

27 This is the fourth of the well-known "stylised facts" that *Kaldor* (1961) put forward to be explained (or reproduced) by the theory of economic growth. Empirical evidence for a constant capital coefficient in seven countries is cited in *Romer* (1989). For a roughly constant capital coefficient in the US during the first half of the 20th century, see *Klein and Kosobud* (1961).

observations and is thus by construction more informational efficient. Hence, to determine I_0, we smooth the yearly series *I/Y* and *Y* with the Hodrick-Prescott filter. Then we multiply the low pass filtered trend values $(I/Y)^*$ and Y^* and refer to the first resulting value as I^*_0. Then we approximate the "secular" growth rate g^* at $t = 0$ with the growth rate of the low pass filtered trend output growth rate $(Y^*_1 – Y^*_0)/Y^*_1$.

It remains to determine δ. Ideally, we would want to resort to a matrix of estimates across countries *i* and years *t*. Yet, since we lack the necessary information, we proceed as suggested by *Harberger* and set $\delta_{i,t} = \delta$. This depreciation rate δ should not be understood in the technical sense. From an economic perspective the depreciation rate has to account for wear and tear as well as for obsolescence of technically still operative capital goods due to changes to relative factor prices or to the introduction of superior capital goods. A glance at depreciation rates used in similar calculations shows that from a macroeconomic perspective, including obsolescence, 10 per cent can be regarded a plausible estimate for δ.[28] Hence, this value is used here.

Accordingly, our capital stock series are calculated as

$$K_t = K_0\,(1 - 0.1)^t + \sum_{i=0}^{t-1} I_i\,(1 - 0.1)^{t-1-i}.$$

For the majority of the countries in our sample, the splined time series for (I/Y) and Y go back to 1950, and the least is to 1960. For each country, we calculate K_t going back as far as the data allow, so that $t = 0$ adopts country specific values. The reason for this is that linear depreciation works fairly quickly so that the unavoidable errors of the base year capital stock estimates fade out the further we move forward in time. Note also that in what follows we shall not consider levels but relative deviations from trend, so that errors in the levels will not affect the validity of the analysis, as long as we are getting the cyclical profile right.[29]

In sum, after a few transparent and theoretically reasonably well founded manipulations to the published yearly time series for Y_t and $(I/Y)_t$, we now can refer to the input that is required to determine the cyclical positions of our 30 countries by means of the capital coefficient v_t.

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28 *Klug and Rebelo* (1990: 130) conclude that a rate of depreciation of 10 per cent is in accordance with "US long term experience." *Benhabib and Spiegel* (1994) for country cross capital stock estimates refer to a depreciation rate of seven per cent. But they report that the estimated parameters of their growth equation are robust against changes of δ between 0.04 and 0.1.

29 With increasing distance from the starting value, our approach is substantially to approximate the evolution of the real capital stock referring to information on gross investment.

Calculation of capital coefficient and capacity utilisation

To estimate of the trend capital coefficient, we again use the Hodrick-Prescott-filter, which is easy to implement and restricts discretion to one exogenous parameter,[30] the intensity of smoothing. This assures reproducibility of our calculations.

The main disadvantage of this filter is the "end point problem", which is due to the fact that symmetric filters become increasingly asymmetric towards the margins of a time series, which may cause substantial revisions as new data points are added. With the Hodrick-Prescott filter, this problem is especially severe for the last four to six data points. One strategy to mitigate this problem is to re-establish symmetry at the margin by forecasting a few data points. The resulting symmetry, however, is of purely technical nature, as the "true" future values, of course, are unknown, so that any improvement of the end point characteristics of the filter is a function of the forecasting accuracy. Since it is difficult to produce reliable economic forecasts for more than a few quarters, and due to the fact that it beyond reach to produce forecasts for six years that convey reliable information about the cyclical profile, we shall not resort to this. As we here are not interested in a reflection of current economic activity, but in a heuristic, explorative review of the past, can mitigate the end point problem by "sacrificing" a few data points and analyse the symmetric filter output only. After filtering, we hence restrict all further analyses to data from 1970 to 2000. Accordingly, at the left margin, where the Penn World Table data for our sample go back to at least 1960, the filter can draw on no less than ten out of sample data points, and at the right margin, where the World Development Indicators extend to at least 2004, we reserve at least four data points for the filter.[31]

On this basis, to determine $CapU_t$ for the 30 countries of the sample, we start with the calculation of I^*_{1950}, for which we multiply $(I/Y)^*_{1950}$ by Y^*_{1950}. (A later initial year than 1950 applies in some cases. However, this it is never later than 1960.) With these starting values we calculate time series for K_t up to 2004 and $v_t = K_t/Y_t$, which is then sent through the Hodrick-Prescott filter, from which we take time series of v^*_t from 1970 to 2000. $CapU_t$ is then computed as $(v^*_t/v_t) - 1$

Normal utilisation implies that $v_t = v^*_t \Leftrightarrow CapU_t = (v^*_t/v_t) - 1 = 0$. In situations with cyclical under-utilisation we will observe $v_t > v^*_t \Leftrightarrow CapU_t < 0$, and in situations with cyclical over-utilisation $v_t > v^*_t \Leftrightarrow CapU_t > 0$.

Plausibility Check

How plausible are the values of our business cycle indicator? For a limited number of countries, we can compare $CapU_{i,t}$ with survey data on capacity utilisation, i.e. with data referring to the

30 See *Hodrick and Prescott* (1997). Apart from the protagonists themselves, *Christodoulakis et al*. (1995), *Razzak* (2001) as well as *Artis* (2003), amongst many others, refer to the Hodrick Prescott-filter. We set the smoothing parameter to $\lambda = 100$, as recommended for yearly data.

31 Thus, the information from the Penn World Tables which complement our time series before 1970 is taken for the calculation of the capital stock in 1969 and to feed the low pass filter at the left margin. Note that they do not enter our analyses elsewhere.

same unobservable variable. Due to pragmatic reasons (data availability), we choose those countries for which the EU documents the results of harmonised surveys (Belgium, Denmark, France, Germany, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain and the UK), as well as the US, Switzerland and New Zealand.[32]

The results of this comparison are presented in Table 1. In 13 out of 14 cases, with the one exception being Belgium, *CapU* is highly correlated with the survey data. In addition, the correlations confirm that, as a rule, *CapU* is more suitable to reproduce capital utilisation from survey data than the univariate (Hodrick-Prescott filtered) output gap. In 11 out of 14 cases the data obtained from the survey is more highly correlated with *CapU* than with the output gap. Superiority of the output gap to reproduce the survey data is only recorded in the case of Belgium, for which we cannot offer a totally convincing explanation.[33] However, taken together, Table 1 indicates adequateness of our measure.

At this point we feel confident to conclude that the business cycle indicator *CapU*, based on the low pass filtering of the capital coefficient, is a valid instrument for the determination of the cyclical position of a country, understood as the degree of utilisation compared to the usual. Accordingly, we can now refer to a reasonably valid and reliable measure of capacity utilisation even for countries where there are no survey data. All that is required are time series of *Y* and *I*.

4.2 Identification of international business cycles

To identify international business cycles, we refer to the $CapU_t$ time series from 1970 to 2000 for the 30 countries of our sample. First, they are subjected to pairwise cross correlation analyses, so that we can identify the degree to which a particular country is integrated into international business cycles. This also allows us to assess whether business cycle integration has strengthened during the observed time period. A principal component decomposition of the data follows, with which we test whether there is empirical evidence for coexistence of a world business cycle along with supra-national business cycles. Finally, we conduct a cluster analysis which can illustrate a hierarchical structure of business cycles.

To gain some insight into the features of $CapU_t$, we summarise at each step how the results change when a HP-filtered output gap is used instead of *CapU*.

[32] The series for the EU countries are based on quarterly data. They start in 1985 or 1987 and are annualised by the author. Data for Austria are only documented for years after the accession in 1995, so that we shall leave this country aside. For the US we use capacity utilisation from the Federal Reserve Board (available from 1980 onwards), for New Zealand the capital utilisation series from the New Zealand Institute of Economic Research (available from 1962 onwards), and for Switzerland survey data on the utilisation of the "technical capacity of the production" in per cent from KOF Swiss Economic Institute at ETH Zürich, which are available from 1967 onwards.

[33] An examination of *CapU* and output gap for Belgium from 1970 to 2000 shows a similar development. However, *CapU* has a lead of one to two years before the output gap in the years 1984 to 1999. In contrast, the survey data series (starting in 1985) is co-moving with the output series until 1990, so that the comparison of the correlation coefficients turns out favourable for the latter.

Cross correlations

Here we examine pairwise correlations between the 30 countries of the sample. For this purpose we calculate all permutations of cross correlations KK_{ij} between the yearly time series $CapU_i$ and $CapU_j$ ($i \neq j$) with a span of ± 1 year.[34] We thus allow for phase shifts of up to one year between the business cycles of different countries. Then we identify for the resulting 870 (30×29) pairwise cross correlations KK_{ij} the highest of three cross correlations conforming to our lead-lag restriction. Finally, we reduce the set of country pairs further and consider only correlations with $r \geq 0.30$, which ensures some minimum correspondence of pairwise business cycles.[35] The results are summarised in Table 2.

Table 2 shows that there are 257 (514/2) positively significant correlations between the cycles of the 30 countries of the sample. This is far more than the expected value of 22 (870/2×0.05), which would have to be expected to occur randomly with $p = 0.05$). Further, the column sums show that synchronous correlations dominate. Still, there are a number of positively significant correlations with phase shifts up to one year.

The country ranking (in descending order regarding their total number of positively significant correlations with the business cycles of other countries) gives some indication about the degree of their integration into supra-national business cycles. Italy is leading the list, followed by five other European countries. Generally, the degree of integration of the countries of our sample is high; it is not before rank 27 that there appears a country, which shows a relatively isolated business cycle (Norway, a crude oil exporter). At rank 28 comes Singapore one of the Asian "tigers", and the lowest cyclical integration, due to these results, show Argentina and New Zealand. This does not seem implausible, as New Zealand is a relatively isolated pacific Iceland and an agricultural exporter; and the business cycle in Argentina has probably largely been dominated by numerous home-made economic crises.

The results of the cross correlation analysis hence appear plausible, indicating that international business cycle integration is indeed a fact. But can we infer anything about the assumption that in the end of the 20[th] century, with intensifying globalisation, international business cycle integration should have increased? In order to answer this question we break down our data into two sub-samples which comprise the 16 years 1970–1985 and the 16 years 1985–2000. Then we repeat the 870 cross correlation analyses for the sub-samples. The number of positively significant correlations amongst the 435 (30×29/2) possible country pairs is given in Table 3, grouped by the degree of correlation.

As Table 3 shows, the number of cyclically highly correlated pairs of countries ($r > 0.8$) has increased significantly after 1985 (from 18 to 39), whereas the number of moderately or lowly

34 As most international business cycle transmission should proceed within a period of one year, a longer lag or lead would imply an implausibly slow transmission and thus spurious cross correlations. It is emphasised that for a detailed examination of phase shifts, we would have to refer to data with higher frequency.

35 With the given number of degrees of freedom, $r \geq 0.30$ is equal to a significance threshold of 5 per cent in a one-tailed test, which is adequate here, as we consider only positive correlations. A *substantive* negative correlation would mean that a positive economic situation in country *i* would impair that in country *j*, which as a rule should not be justifiable.

correlated country pairs have decreased. Cumulatively, the correlations below 0.7 have decreased, whereas those of 0.7 or higher have increased. Thus, the picture is mixed; the group of the cyclically closely integrated countries has doubled to almost 40, while the number of cyclically loosely connected countries has decreased from nearly 250 to 150. Note that this observation is in line with the general observation (see section 1) according to which the typical pattern of the economic globalisation has lately been the formation of blocks.

Finally, let us check how the findings from the cross correlation analyses are affected when we refer to the HP-filtered output gap instead of our preferred business cycle indicator *CapU*. The results are summarised in Table 4.

Table 4 shows that the degree of international business cycle integration according to *CapU* is overall somewhat stronger than that reflected by the HP-filtered output gaps. In the first case there are 257 out of 435 positively significant correlations, compared to 237 out of 435 possible pairs in the latter. Yet, a comparison of the seven grouped levels of correlation is inconclusive; and in the 0.6–0.8 range there are eight more significant pairs for the output gap than for *CapU*. It does not seem appropriate to conclude from these relatively similar results that there are strong systematic differences. However, it can be stated that this comparison does not stand in contrast to the assumption that the *CapU*, due to its construction, should be superior to the univariate output gap as a business cycle indicator.

Pairwise correlation can reveal international integration of countries (pairwise or overall). Yet, it cannot clarify the structure between multiple business cycles. For this, other methods are more appropriate. We shall turn to these now.

Principal component analysis

We now submit the 30 *CapU* time series to a principal component analysis. This will serve to get an idea of the number of underlying dimensions that can interpreted as international cycles, as well as of the degree to which the countries can be associated with these dimensions.

The *CapU* series are by construction stationary, which implies that we can work with the conventional instruments of factor decomposition used in cross-sectional analyses.[36] We refer to the standard method – principal component analysis – which among factor-analytic methods is the one that requires least assumptions about the covariance structure of the data.

Principal component analysis is a method to reduce a data to a low number of dimensions.[37] In particular, a principal component is a synthetic variable that results from a linear combination of observed variables. The starting point is a matrix of k variables that can be expected to be related to each other (correlated), and n observations (here k corresponds to the 30 business cycles reflected by $CapU_t$ and n to the 31 yearly observations). Each variable $X_1, \ldots, X_k$ can

[36] Augmented Dickey-Fuller tests for the 30 series show that stationarity is not only implied by construction, but also statistically given. The series as well as the test statistics are available from the author upon request.

[37] See e.g. *Johnston* (1984) and *Jolliffe* (1986).

exactly be expressed as a linear combination of k principal components $H_1, ..., H_k$. For the i-th variable, observed at the j-th case, we get:

$$X_{ij} = a_{i1} H_{1j} + a_{i2} H_{2j} + ... + a_{ik} H_{kj} \, , \, (i = 1, ..., k; j = 1, ..., n) \, .$$

The algorithm now determines what share of the overall variance of the k observed variables can be reproduced with $r < k$ principal components,

$$X_{ij} = a_{i1} H_{1j} + a_{i2} H_{2j} + ... + a_{ir} H_{rj} + R_{ij} \, , \, (i = 1, ..., k; j = 1, ..., n) \, ,$$

where R_{ij} stands for the unexplained rest when reducing the linear combination to r principal components observed at the j-th case of the variable X_i. The components are subsequently determined by ordinary least squares in a way that the rest R_{ij} is minimised. The loadings $a_{i1}, ..., a_{ir}$ correspond to regression coefficients which would result from the multiple regression of variable X_i on the principal components. How many principal components are required to reproduce the data? The literature suggests variance shares of 70 to 90 per cent. Yet, as any threshold is arbitrary, looking at explained variance leaves room for discretion. In contrast to this, the eigenvalue-rule provides an exact number of components to be extracted: As the number of potential components is equal to the number of variables k and since the sum of the explanatory contributions of all potential principal components amounts to 100 per cent, an explanatory contribution below $(100/k)$ per cent (corresponding to an eigenvalue lower than unity) implies that the this component contributes less to the explanation of the overall variance than an average variable. The eigenvalues as well as the variance shares of the principal components with eigenvalues exceeding unity resulting from a principal components decomposition of *CapU* are given in Table 5. The unrotated factor loading matrix is reproduced in Table 6.

Table 5 shows that according to the eigenvalue-rule seven principal components should be extracted. The explained variance shares, however, decrease rapidly. The first four principal components cumulatively reproduce more than 70 per cent of the overall variance of *CapU*, so that this would represent the first acceptable solution according to the minimum variance criteria. Whether the principal components 5 to 7 should be referred to hence depends on the interpretability of their loading structures.

A straight-forward interpretation of this principal components decomposition is a follows: The cycle that is common to the largest subset of countries in the sample will emerge as the first principal component, representing the global business cycle (according to the country sample). Now, such a component indeed emerges from our data, as can be seen in Table 6, where the factor-loading matrix is sorted in descending order with respect to the strength of the loadings on the first principal component. The countries are thus ranked according to their congruence with our world business cycle.

Note that regarding the first principal component, the picture that emerges largely replicates the findings from the cross correlations (see Table 2). A large number of countries are cyclically co-moving with a number of other countries and hence show high loadings on the first component that reflects the global cycle. Insignificant loadings on the first component (below |0.3| relate to Singapore, Argentina, New Zealand, Norway and Denmark only, i.e. for countries that already revealed low numbers of significantly positive cross correlations (see Table 1). Consequently, these countries are also cyclically independent from our global cycle.

The evolution of the world business cycle represented by the first principal component is shown in Figure 1. To the right of the vertical line, which marks the end of the in-sample period, we indicate the (provisional) evolution of the first principal component with data until 2004 (where we face an end point problem and a high probability of revisions to *CapU*). Yet, the provisional data points are well in line with what we so far know about the burst of the IT-bubble, the end of the "new economy" and the subsequent recovery of the world economy.

Figure 1 shows the first principal component, which we interpret as the world business cycle. The graph with its peaks and troughs reflects the history of world business conditions since 1970 remarkably well. The boom of the early 1970s is followed in 1974 by the first oil price shock, after a low in 1975 a light recovery follows, which then however, ends in a new low in the course of the second oil crisis in 1982. A new peak is reached at the end of the 90s, followed by a recession lasting until 1993. For the rest of the timeframe analysed here, until the year 2000, an uninterrupted upswing of the world business cycle.

The world business cycle component W_t that we can determine with this method represents roughly one third of the cyclical variance of *CapU* across the 30 countries of the sample. This is a plausible magnitude, as it implies that some two thirds of the variance have to be traced back to other factors, where, apart from noise and country-specific business cycle factors, one has to take into account different business cycles below the global level.

Before further interpretation, it is in order to mention that solutions with more than one principal component are not unique, as each orthogonal transformation of the factor structure is equivalent (rotation problem). Since the first solution is often difficult to interpret, the default strategy (regularly implemented in software packages) is to perform a rotation before going on to interpret the loading matrix. However, this would not be appropriate here. Our theoretical starting point of a world business cycle W_t, which is accompanied by business cycles with supra-national dispersion R_t as well as business cycles comprising groups of countries with similar socio-economic, political or technological characteristics S_t, predicts that we should find a first component on which most countries load positively. This is exactly the case. As rotation would affect this component, we shall continue refer to the *unrotated* loading matrix. To ease interpretation, for principal components numbered 2 to 7, we suppress loadings which amount to less than $|0.1|$ and hence are practically equal to zero. For the interpretation we still refer to moderate loadings of at least $|0.4|$. Finally, we highlight loadings above $|0.5|$.

Now, Denmark, Sweden, Norway, the UK, Finland, New Zealand, Australia and Canada load highly or moderately positive on the second principal component. This country group of comprises only Scandinavian and Anglo-Saxon countries (and with the exception of USA, Ireland and Iceland all countries of that group), so that we can interpret it as a Scandinavian/Anglo-Saxon business cycle. Negative loadings on the second principal component are recorded for Germany, Portugal, Uruguay, Singapore, Austria and Hong Kong. This group, however, is so heterogeneous, that an interpretation is difficult and accordingly, we do not suggest a corresponding supra-national cycle.

Singapore, Israel, Chile, Greece, Switzerland, Norway and Argentina show highly to moderately positive loadings on the third principal component, whereas South Korea and the Netherlands load highly to moderately negative on it. Again, this appears random and accordingly, we shall not try to find an interpretation.

Australia, the USA and Ireland load highly to moderately positive on the fourth principal component, suggesting business cycle integration of those countries under US leadership.[38] A highly to moderately negative loading is recorded for Israel. Comparison with the second principal component, which suggested a Scandinavian/Anglo-Saxon business cycle, shows high loadings on the fourth principal component for exactly those three Anglo-Saxon countries – Australia, the US and Ireland – which do not load highly on the second component. Thus, with the exception of Iceland, all Scandinavian and Anglo-Saxon countries can be assigned to one of two complementary business cycles.

For the fifth principal component highly to moderately positive loadings can be detected for Hong Kong, New Zealand and Argentina. Again, we do not see any obvious interpretation. The same applies to the sixth and seventh principal components.

In sum, the principal component decomposition confirms our world business cycle model. The first principal component can readily be interpreted as a world business cycle. The subsequent principal components allow identifying a Scandinavian/Anglo-Saxon and a (smaller) complementary Anglo-Saxon business cycle. Remarkably we cannot identify a EEC/EC/EU, a South American or an Asian business cycle. Whether this it due to drawbacks of our methodology, or whether business cycle integration within these country groups was indeed comparatively little pronounced during the last three decades has to remain open at this stage.[39]

The next and final step of our empirical analyses is a hierarchical cluster analysis. As this joins similar observations down to the level of pairs, this will allow us considering the possibility of business cycle integration within Europe, South America and Asia in detail.

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[38] As the dominant economy of the second half of the twentieth century, the US may be expected to play leading part in world business cycles. With the US-dollar as an international invoice and reserve currency, highly liquid bond markets which in theory and practice deliver the reference value for the "safe" interest rate as well as a dynamic production and consumption, the US economy contributes significantly to the international formation of prices end expectations; see *Gregory and Head* (1999).

[39] The finding does not change qualitatively when we conduct the principal component decomposition with the output gap. Indices for some cyclical integration within Latin America are also found by *Bezmen and Selover* (2005), so that our results may indeed be correct. That failure of the three Southeast Asian emergent economies (Hong Kong, Singapore and South Korea) to load on a joint component can possibly be attributed to the fact that Singapore (as revealed by the correlation analyses) shows a very low degree of cyclical integration into our country sample. Finally, it should be kept in mind that a particular clustering is contingent on the sample, so that our findings are heuristic rather than conclusive.

Hierarchical cluster analysis

Cluster analyses are methods that decompose a data set into different groups (clusters). The algorithm relies either on *distinguishing between different clusters* or on the *similarity within a cluster*. For our purposes, we proceed as follows.

First, we transpose our matrix of 30 variables and 31 observations so that we obtain a data matrix with 31 years as variables and 30 countries as observations. Then we subject this matrix to a hierarchical cluster analysis with the squared Euclidian distance

$$\sqrt{} \Sigma \, (CapU_i - CapU_j)^2$$

as measure of similarity. We determine the cluster structure by means of the Ward-algorithm. Starting at the lowest level of dissimilarity, variable median values are successively calculated for all possible clusters. Then the quadratic Euclidian distance between all observations (countries) is determined. The clustering then proceeds according to the minimum increase in the squared Euclidian distance. This clustering method considers all variables equally when determining the within group variance. Thus, homogeneity *within* a group is the focus (in contrast to algorithms aiming at clear-cut separation *between* clusters). This corresponds to a focus on commonality of the business cycle within a country group rather than on delimiting one cycle from the other.

Figure 2 shows the resulting dendogram. We shall examine the cluster structure from the left to right, corresponding to bottom to the top of the hierarchy. The countries with the most similar business cycles according to *CapU*, are a group of four (France, Italy, Switzerland and Japan) then two groups of three (the Netherlands, USA and Australia as well as Canada, the UK and Sweden) and, finally, the pairs Austria-Germany and Belgium-Spain. Somewhat less similar to each other are Ireland-Portugal and Denmark-Norway. Furthermore, clusters of rather loosely connected country pairs are Hong Kong-South Korea and Argentina-Uruguay. Accordingly, in contrast to the principal component analysis, the cluster analysis shows a certain cyclical affinity within the Southeast Asian as well as South American countries in our sample. The distance measures for the cluster Hong Kong-South Korea, however, is higher than for any other two-country cluster. Argentina and Uruguay are cyclically quite dissimilar, as the distance measure shows. The reason that they nevertheless form a cluster is simply that they exhibit even more dissimilarity to the other 28 countries in our sample.

Chile and Singapore exhibit are loosely associated to a cluster of 12 European countries plus Japan and Israel (the top 14 countries in Figure 2), which is then also joined by Hong Kong and South Korea further to the right, but not by Argentina and Uruguay. Those two countries constitute an own group until the 30 countries are grouped into *three* clusters only. It takes until the 30 countries are grouped into *two* clusters that a loosely connected cluster emerges, which comprises all Scandinavian countries except Iceland as well as all Anglo-Saxon countries of the sample (the 12 countries at the bottom of Figure 2).

Accordingly, in qualitative terms the cluster analysis replicates the finding from the principal component analysis. Apart from a general world business cycle, we identified a Scandinavian/Anglo-Saxon and a smaller, complementary Anglo-Saxon business cycle component. The countries that constitute those two components exhibit a distinct overlapping with those that form one of three clusters in the hierarchical cluster analysis. Also the pronounced cyclical synchronism between Australia and the USA, which is indicated by the fourth principal component, is confirmed by the cluster analysis.

At this level, apart from Argentina and Uruguay, the rest of the countries of the sample unite into another cluster. A closer examination of the 18 countries constituting this cluster shows (as the non-European countries Chile, Singapore, Hong Kong and South Korea only join at a relatively high measure of dissimilarity), that the non-Anglo-Saxon and non-Scandinavian European countries plus Iceland, Israel and Japan constitute the second high-level business cycle.

Accordingly, the two major international business cycles in the last third of the 20th century were on the one hand formed by Austria, Belgium, France, Germany, Greece, Iceland, Ireland, Israel, Italy, Japan, Luxembourg, Portugal, Spain and Switzerland and on the other hand by Australia, Canada, Denmark, Finland, the UK, New Zealand, Netherlands, Norway, Sweden and the USA. These two groups partly correspond to supra-national cycles S_j uniting countries that are geographically linked or close and in some respects to cycles comprising countries that may be geographically remote but are similar regarding socio-economic and political characteristics S_k.

This finding is in line with our world business cycle model, according to which the international business cycle should be understood as hierarchical and at the same time polycentric.[40]

5 Summary and conclusion

This paper addresses the question in how far the business cycles of different countries are interconnected. After a conceptual discussion, in which a simple model of the international business cycle is developed, we introduce a new approximation of the variable "capacity utilisation" that relies on two time series only (GDP and gross investment rate) and yet allows for an internationally perfectly comparable determination of the cyclical position of a country. After some plausibility tests, we conclude that this business cycle indicator is a valid and reasonably reliable instrument that promises to be superior to the widely used output gap.

With this method we calculate for 30 countries yearly time series for capacity utilisation from 1970 to 2000. We then refer to these data in order to test a series of hypothesis about international business cycles.

Cross correlation analyses show a high degree of international cyclical integration, where during the last few decades the number of cyclically highly correlated country pairs has increased, whereas that of the moderately and less correlated country pairs has decreased. Accordingly, the typical pattern of economic integration seems to have been the consolidation of economic (and business cycle) blocks rather than general globalisation.

A principal component analysis yields a first component that can be interpreted as a world business cycle. This explains roughly one third of global cyclical variance in our data. The further components indicate a Scandinavian/Anglo-Saxon and a smaller Anglo-Saxon business cycle.

[40] Again, the findings do not change qualitatively when we refer to the output gap instead of *CapU*.

This finding can largely be replicated by a hierarchical cluster analysis. Moreover, the non-Anglo-Saxon and non-Scandinavian European countries plus Iceland, Israel and Japan appear to form another business cycle. Finally, there is indication of moderate cyclical synchronism within South America and Southeast Asia.

Taken together, the analyses deliver support to a model, according to which the international business cycle should be seen as a polycentric hierarchy of cycles.

Interestingly, with our methods and data, we cannot detect pronounced indication for an EEC/EC/EU, a South American or an Asian business cycle.

A focus on chronology in the formation of economic blocks might be a promising extension of the approach outlined in this paper. Other directions to proceed from here would be to extend the analysis to additional countries or to limit the country sample and refer to quarterly instead of yearly data.

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Table 1: Pearson correlation, *CapU* and output gap with survey data

	CapU	Output gap	Period
Spain	0.82	0.51	1987–2000
USA	0.80	0.77	1970–2000
Italy	0.80	0.85	1985–2000
Ireland	0.72	0.24	1985–2000
Netherlands	0.71	0.57	1985–2000
Franca	0.67	0.81	1985–2000
Portugal	0.74	0.32	1987–2000
UK	0.74	0.68	1985–2000
Switzerland	0.71	0.70	1970–2000
New Zealand	0.66	0.49	1970–2000
Luxembourg	0.64	0.43	1985–2000
Germany	0.60	0.28	1985–2000
Denmark	0.57	0.57	1987–2000
Belgium	0.28	0.60	1985–2000

Table 2: *$CapU_{it}$*, significantly positive cross correlations, lead/lag ≤ 1 year

Land	Lead	Coincident	Lag	Sum (line)
Italy	0	18	7	25
Iceland	1	13	9	23
France	3	16	3	22
Spain	1	13	8	22
Belgium	1	14	6	21
Luxembourg	1	11	9	21
Canada	6	11	4	21
Portugal	1	12	7	20
Chile	6	11	3	20
Germany	3	10	7	20
UK	11	7	2	20
Switzerland	2	12	5	19
Japan	6	12	1	19
Netherlands	5	10	4	19
Australia	13	3	3	19
Finland	3	9	6	18
Greece	8	6	3	17
Hong Kong	4	11	1	16
Uruguay	4	6	6	16
Austria	3	9	3	15
South Korea	6	9	0	15
USA	6	9	0	15
Israel	1	6	8	15
Sweden	4	6	5	15
Ireland	5	4	6	15
Denmark	13	2	0	15
Norway	5	4	0	9
Singapore	4	4	0	8
New Zealand	1	3	3	7
Argentina	3	2	2	7
Sum (column)	130	263	121	514

Table 3: Significantly positive cross correlation, lead/lag ≤ 1 year, by period

Correlation r	1970–1985	1985–2000
r > 0.9	3	10
r > 0.8	15	29
r > 0.7	50	44
r > 0.6	60	28
r > 0.5	68	38
r > 0.4	63	40
r > 0.3	53	44
Sum (column)	312	233

Table 4: Significantly positive cross correlation, lead/lag ≤ 1 year, *CapU*, output gap

Correlation r	*CapU*	Output gap
r > 0.9	1	0
r > 0.8	4	9
r > 0.7	24	27
r > 0.6	42	47
r > 0.5	60	47
r > 0.4	65	59
r > 0.3	61	48
Sum (column)	257	237

Table 5: Principle component extraction, *CapU* 1970–2000

Principle component	Eigenvalue	Variance explained %	Cumulative variance explained %
1	10.5	35.1	35.1
2	4.8	15.9	51.0
3	3.3	11.1	62.0
4	2.6	8.8	70.8
5	2.2	7.3	78.2
6	1.6	5.2	83.4
7	1.2	4.0	87.4

Table 6: Factor loadings matrix, *CapU* 1970–2000

	1	2	3	4	5	6	7
France	**0.90**		-0.11	-0.22	-0.27		
Italy	**0.89**		0.19		-0.14	-0.15	
Spain	**0.86**	0.16	-0.17	-0.29	0.10	-0.24	
Iceland	**0.83**		0.15		-0.02	-0.20	0.14
Belgium	**0.82**		-0.28	-0.28	0.23	-0.19	
Luxembourg	**0.78**	-0.16	-0.30	-0.18		-0.24	-0.28
Canada	**0.78**	0.43	-0.21	0.20	0.19		
Japan	**0.72**	-0.27	0.31	-0.24		0.36	0.11
Finland	**0.69**	**0.57**		-0.14	-0.30	-0.18	0.16
Portugal	**0.67**	**-0.53**	-0.16	0.26		-0.23	
Switzerland	**0.68**	0.15	0.43	-0.27	-0.28	0.16	-0.22
UK	**0.64**	**0.62**	-0.15	0.05	0.19	0.17	0.20
Netherlands	**0.61**		**-0.53**	0.28	-0.34		-0.25
Chile	**0.57**		**0.56**	0.18	0.20	0.24	-0.24
Austria	**0.57**	-0.42		-0.32	0.22	0.17	-0.27
Sweden	**0.55**	**0.70**	-0.21	-0.14	-0.20	-0.15	
Germany	**0.55**	**-0.68**	0.14	-0.07	0.15	0.13	-0.24
Greece	**0.53**	-0.17	**0.55**		-0.43	0.23	
Hong Kong	**0.51**	-0.41		0.18	**0.59**	0.15	
USA	**0.51**		-0.30	**0.64**	0.21	0.28	
Israel	0.45		**0.57**	-0.47	0.10	-0.14	0.19
South Korea	0.44	-0.19	**-0.53**	-0.11	0.45	0.39	0.22
Ireland	0.39	-0.37	-0.17	**0.54**	-0.11	-0.18	0.44
Australia	0.40	0.46	0.11	**0.70**	-0.18		
Uruguay	0.36	-0.47	0.32	0.38	-0.18	-0.39	
Denmark	0.26	**0.76**	0.18	0.11		0.42	
Singapore	0.04	-0.46	**0.61**	0.12		0.13	0.46
Argentina	0.02		0.43	0.34	**0.50**	-0.47	-0.30
New Zealand	-0.05	**0.56**	0.28	-0.16	**0.56**	-0.21	0.28
Norway	-0.09	**0.63**	0.43	0.35	0.27		-0.24

Figure 1: World business cycle W_t (first principal component) 1970–2004

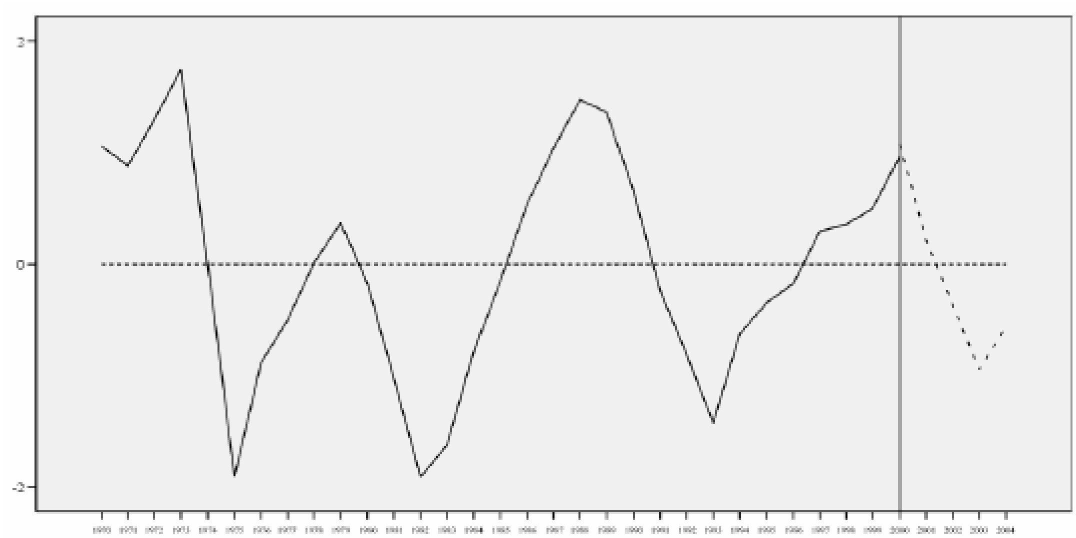

Figure 2: Dendogram, hierarchical cluster analysis, *CapU* 1960–2004