

# Examining the decoupling hypothesis for India

Shruthi Jayaram\*    Ila Patnaik    Ajay Shah

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## Abstract

This paper examines the decoupling hypothesis for India. We analyse business cycle synchronisation between India and industrial economies, particularly the United States, over the period 1992 to 2008. The evidence suggests that business cycles in India exhibit increasing co-movement with those in industrial economies over this period. Indian business cycle synchronisation is stronger with advanced industrial countries as a whole as opposed with the co-movement found with the US.

JEL Codes: E32, F15, F41.

Keywords: Business cycles, synchronisation, decoupling, trade, dynamic correlation.

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# 1 Introduction

India has seen greater integration with the world economy through trade in goods and services, and through financial integration, over the past two decades. Has this integration has been accompanied by business cycle synchronisation with the rest of the world? Or is India in a period of high economic growth which is decoupled from the rest of the world?

The literature on developed countries suggests that increasing trade intensity leads to business cycle synchronisation, but there is no consensus, either in the theory or in the evidence, on what might come about with developing economies. This has given rise to the debate about a possible ‘decoupling’ of the business cycle in emerging markets, especially in India and China, from that found in developed countries. The apparent divergence in the performance of different regions of the world economy in 2008 brought the theme of decoupling to the forefront of debates on the international economy [Kohn, 2008].

The early literature, which focused on developed countries, found ample evidence that increasing trade intensity leads to increased business cycle synchronisation [Frankel and Rose, 1998]. More recent work on emerging markets shows mixed results, with Agenor et al. [2000] and Calderon et al. [2007] finding an increase in output correlations over time and Fidrmuc et al. [2008] finding evidence of decoupling. Chan and Khong [2007] finds that Asia-Pacific economies tend to be more correlated with Japan than the US. Studies such as Kose et al. [2003] find that increased trade and financial liberalisation adds to contagion of macroeconomic and trade shocks. The findings of Kose et al. [2008] seem to suggest evidence in favour of decoupling between industrial countries and emerging economies.

Disagreements in the empirical literature arise from the differences in countries and time periods studied, alternative detrending techniques and business cycle “identification” procedures, accounting for production asymmetries and the impact of inter-industry trade (specialisation and divergence) versus that of intra-industry trade (common shocks and convergence) on the business cycle [Kose and Yi, 2001, Frankel and Rose, 1998, Krugman, 1993]. Data availability, changes in the policy environment and structural breaks in trend growth are part of the accepted difficulties of estimating business cycle synchronisation in emerging markets.

While anecdotal evidence for India suggests increased linkages with the world, the systematic evidence on this is limited. India is part of the sample of countries studied by Agenor et al. [2000] and Fidrmuc et al. [2008]. The latter paper examines the case of India and China and finds evidence in favour of decoupling. Similarly, Akin and Kose [2008] find that countries of

the Emerging South (that includes India and China) have decoupled with industrial countries over time.

Another dimension of exploration lies in linkages with the US as opposed to other industrial countries. The US has strong trade and financial links with India<sup>1</sup>. In addition, Indian monetary policy has often consisted of a *de facto* pegged exchange rate, which generates a channel for transmission of US monetary policy into the Indian economy. Hence, it is useful to measure the extent to which the Indian business cycle is synchronised with the US, as opposed to synchronisation with a broader set of industrial countries.

In this paper, we use output and trade data on India and the rest of the world to investigate three questions:

1. How has the Indian business cycle behaved during world expansions and recessions?
2. Has there been a change in business cycle synchronisation over time between India and the rest of the world?
3. Does India have particularly strong linkages with the US, or is the comovement stronger with a broad set of industrial countries.

We construct a data set consisting of measures of industrial production for India and advanced economies and a coincident indicator for the US business cycles. In addition to exploratory data analysis, we use the Harding-Pagan index of concordance to measure the extent of synchronisation.

Our results show that the Indian business cycle is linked to business cycle conditions in the US and the rest of the world with statistical and economic significance. We find that there is a significant increase in this synchronisation over the period 1992-2008. Finally, we find that the Indian business cycle is more synchronised with a composite of all advanced countries, rather than just the United States.

This paper contributes to the literature on decoupling that focuses on the changes in the pattern of comovements between industrial and developing countries. It complements the multi-country empirical research in the field by studying the case of India in detail.

The remainder of this paper is divided into the following sections. Section 2 discusses what economic theory and existing evidence tells us about business cycle synchronisation for developing countries. Section 3 deals with methodological issues such as business cycle identification and detrending,

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<sup>1</sup>Exports to the US accounted for 13 percent of India's exports in 2007, and has long been India's biggest trade partner

and also discusses our dataset and its limitations. Section 4 presents preliminary findings based on graphical analysis. Section 5 first describes the Harding-Pagan index of concordance and then discusses our main results. It also presents sensitivity analyses of the results. Section 7 concludes and suggests areas for further research.

## 2 Business cycle synchronisation

There is no consensus in the theoretical literature on the impact of increasing trade and financial liberalisation on business cycle integration. Some theoretical arguments predict decoupling while others predict synchronisation. An empirical literature has sprung up, aiming to resolve this debate.

### 2.1 The theory

There are many channels through which synchronisation might come about. The first is the demand channel, which emphasises that demand shocks in one economy lead to income shocks in its trading partners. Thus, as intra-industry trade grows, output correlations increase leading to business cycle convergence [Frankel and Rose, 1998].

The second argument emphasises financial market linkages and ‘contagion’. As financial integration increases, capital flows in different countries are synchronized through various channels of financial contagion including herd behavior and information asymmetry. Region-based investment decisions and positively correlated capital shocks also lead to synchronisation [Kose et al., 2003].

The third channel through which comovement comes about between two countries is monetary policy. Significant *de facto* openness on the capital account is now found in almost all large countries. Under these conditions, when a country chooses to engage in exchange rate pegging, whether *de facto* or *de jure*, it loses autonomy of monetary policy. As an example, countries in the Middle East have adopted US monetary policy through the use of currency boards. This induces comovement. In the Indian case, there is evidence of periods of *de facto* exchange rate pegging to the US dollar [Patnaik, 2007], and of the consequent loss of monetary policy autonomy [Patnaik, 2005].

Commodity price movement, such as the price of oil, and remittances from industrial countries to developing countries constitute other channels through which business cycles are transmitted.

However, Krugman [1993] argues that inter-industry international trade leads to specialisation or the creation of a vertical production structure. As specialisation increases, business cycles diverge due to sector-specific shocks. Similarly, increased financial integration also promotes product specialisation, as firms use portfolio diversification to insure against country-specific shocks. This can increase business cycle asymmetry.

## 2.2 The empirical evidence

The early literature focusing on developed countries found significant evidence that increasing trade integration led to increased business cycle synchronisation. Frankel and Rose [1998] estimated a instrumental variable regression model to test if bilateral trade intensity explains cyclical output correlations in the industrial world. Shin and Wang [2003] test a similar model, also controlling for intra-industry trade. Both studies show that increasing trade intensity led to increased business cycle synchronisation.

The literature on emerging markets has mixed results. Agenor et al. [2000] and [Rana, 2008] present stylised facts to show that output correlations with developed countries have increased over time. Calderon et al. [2007] present similar results, but find that controlling for production structure asymmetries between countries yields lowered output correlations. Chan and Khong [2007] finds that Asia-Pacific economies tend to be more correlated with Japan than the US, and this synchronisation between Asia-Pacific economies is also confirmed by Kumakura [2006] and Moneta and Ruffer [2009].

Some studies find evidence of decoupling. Kose et al. [2003] find that increased trade and financial liberalisation adds to contagion of macroeconomic and trade shocks but the effect for developing countries is weak. Fidrmuc et al. [2008] conduct cross-spectral analysis between quarterly GDP of the OECD countries and emerging markets such as India and China. They estimate dynamic correlations, and find that over the sample period 1996-2006 there is little coherence, in business cycle frequencies, of India and China with OECD. Kose et al. [2008] find that while there is no strong evidence in support of world wide convergence of business cycles, there is evidence of inter group convergence within industrial countries and within emerging economies. This seems to suggest decoupling between industrial countries and emerging economies.

## 2.3 Business cycles in India

The existing empirical literature in India in the field of business cycle analysis deals with the problems of dating the cycle, and examining leading, coinci-

dent and lagging indicators [RBI, 2006, Patnaik and Sharma, 2002, Dua and Banerji, 2006, Chitre, 2001]. These studies find evidence of market-oriented cycles post-1991 and also that some indicators of world output are relevant as leading indicators of Indian cycles [RBI, 2006, Mall, 1999]<sup>2</sup>. Some of the studies on international business cycle synchronisation include India as one of many countries in a multi-country dataset [Kose and Yi, 2001, Agenor et al., 2000, Calderon et al., 2007]. This limits their ability to obtain greater detail on India. However, studies like Fidrmuc et al. [2008], Akin and Kose [2008] which are closer to studying business cycle synchronisation of India and China as a group, or as part of the smaller group, with the industrial world find some evidence in favour of decoupling.

### 3 The data set and definitions

#### 3.1 Identifying the business cycle

We follow the NBER approach and study the trend-cyclical component of seasonally adjusted data. However, in order to address the “classical expansion” faced by emerging markets where all measures of output have been on a steady increase over the past decade or so, we modify this approach to study cyclical fluctuations in point-on-point growth rates of output. Effectively, we are studying growth rate cycles.

This approach is based on the premise that shocks to both the trend component and the cyclical component of output are relevant to business cycle analysis. It has the advantages of not modifying data properties via detrending, and lowering the impact of possible structural breaks on the results. This is especially relevant to emerging economies, where recent work on trend-cycle integration in developing countries suggest a stochastic data generating process for the trend component of output [Aguiar and Gopinath, 2007].

An alternative method to identify the business cycle component of an output series is to detrend it using a time or frequency domain filter<sup>3</sup>. However, detrending can induce spurious cycle and filter-sensitivity [Canova, 1998, Harvey and Jaeger, 1993]. Over the past two decades, India has seen several economic and institutional changes, including in its exchange rate regime, monetary policy framework, financial regulatory framework and trade policy

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<sup>2</sup>Most of these studies look at growth cycles, i.e. deviations of output from a designated “trend growth”.

<sup>3</sup>Commonly used filters include the Hodrick-Prescott filter, the Baxter-King filter and the Christiano-Fitzgerald filter

structure. India has globalised rapidly and witnessed rapid economic growth. Given this institutional environment, the case for trend-cycle interaction is strengthened.

### 3.2 Data

The literature on business cycles in India uses monthly data for industrial production as a proxy for output, for two reasons. First, structural changes in the Indian economy over the last two decades have given a morphing of monsoon-related cycles in the period 1950-1991 into growth/growth rate cycles in the 1990's [Patnaik and Sharma, 2002]. This makes studying investment-inventory cycles relevant only after 1991. Second, any meaningful analysis of cyclical fluctuations require data of quarterly or monthly frequency. This is not easily available in India. Since quarterly GDP data is available only from 1996, the use of either annual or quarterly GDP data is inadequate. Data for employment, retail sales and income are not available on a monthly or even quarterly basis.

The dataset that we create runs from August 1992 till December 2008. Monthly data for the Indian Index of Industrial Production (IIP) is obtained from the Business Beacon database published by the Centre for Monitoring Indian Economy (CMIE). We source data on merchandise exports, exports of goods and services, GDP, gross flows on the current and capital account, corporate profits after tax, and corporate revenue growth from the same database.

We use the Conference Board coincident indicator for the United States. It is a composite of the Index of Industrial Production, non-farm payroll employment, personal disposable income excluding transfers and retail manufacturing and sales<sup>4</sup>. We source the US Index of Industrial Production from the website of the Federal Reserve Bank.

The Advanced Economies Index of Industrial Production (AEIIP) is a weighted index of non-seasonally adjusted industrial production for 22 countries classified as “industrial” by the International Monetary Fund. The value added in industry in the year 2000 (expressed in US dollars) is used as a weighting factor for each country<sup>5</sup>. This data is sourced from the IMF-IFS. Similarly, the data for world trade used in the sensitivity analysis is obtained from the IMF-IFS.

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<sup>4</sup>This indicator is available from The Conference Board’s website at <http://www.conference-board.org/economics/bci/>

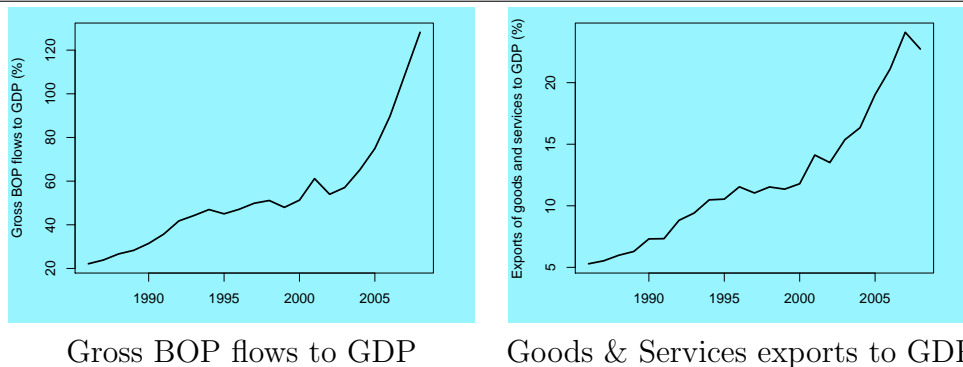
<sup>5</sup>Bases are harmonised to 2000=100 using chain-linking via ratio-splicing.



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**Figure 1** Increased integration with the the rest of the world

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**Table 1** Ratios of trade and capital flows to GDP in India

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Sub-Sample	Trade/GDP (%)	(CA+KA)/GDP (%)
1992-1997	20.44	45.83
1997-2003	23.28	53.77
2003-2008	34.26	93.94

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## 4 Exploratory analysis

In this section, we present graphical evidence of India's trade and financial integration with the world economy and examine how Indian macroeconomic variables behaved during world expansions and recessions. We examine evidence of change in business cycle synchronisation across the period 1992-2008.

Industrial production indices are measures of quantity and thus represent real variables. We seasonally adjusted unadjusted using X-12 ARIMA<sup>6</sup>. Following Frankel and Rose [1998], who break their sample into four equal parts to examine the increase in integration, the sample period is cut across into three roughly equal sub-samples. The break-points chosen are August 1997 and August 2003.

### 4.1 Increased integration

There has been a sharp increase in India's integration with the world economy on both trade and financial flows, as shown in Figure 1, which shows graphs for the growth of gross flows on the BOP to GDP, and the exports of goods and services to GDP. Table 1 shows averages of these values for three periods of interest.

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<sup>6</sup>Model specifications were verified using the HEGY seasonal unit root tests and residual diagnostics

In the context that there is no consensus in the literature on the impact of increasing trade and financial liberalisation on business cycle integration, establishing or rejecting the synchronisation hypothesis is an important element in the debate. The sharp increase in economic integration suggests that business cycle synchronisation could have changed over these periods, thus necessitating separate measurement of business cycle synchronisation.

**Table 2** Correlations of weekly returns on the CMIE Cospi stock market index against global stock market indexes

	UK FTSE-100	Japan Nikkei-225	US S&P 500
1992-1997	-0.008	-0.038	-0.023
1997-2003	0.184	0.168	0.167
2003-2008	0.463	0.390	0.339
Full period	0.192	0.149	0.150

Table 2 shows correlations of the CMIE Cospi stock market index, which depicts the total returns on the broad market in India, against three major international indexes: the US S&P 500 index, the Japanese Nikkei 225 index and the UK FTSE-100 index. With all these three indexes, across the three sub-periods, correlations have gone up. This suggests increasing synchronisation with the world economy. In the latest period, the correlation against the UK FTSE-100 (0.463) and the Japanese Nikkei 225 (0.39) exceeds the correlation with the US S&P 500 index.

## 4.2 Preliminary evidence

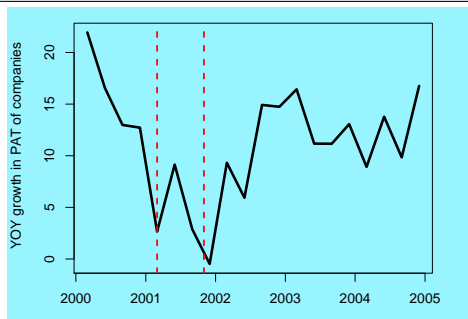
To look at some preliminary evidence about whether business cycles in India have been “coupled” or “decoupled” with those in industrial countries, we now look back towards the last US business cycle as defined by the NBER (starting in March 2001 and ending in November 2001). Figure 2 shows data for India during that period. This shows that the growth of exports, industrial production, corporate revenues and corporate profits all fell to very low levels.

Since the above analysis is limited to only one business cycle downturn in the US, it only presents anecdotal evidence of greater synchronisation. However, graphs for a longer sample period also suggest similar behaviour. Industrial production in India across business cycle peaks and troughs over the period 1992-2008 also show increased integration. Point-on-point growth rates between the US coincident indicator and Indian IIP, as well as those between industrial production in advanced economies and in India also suggest the same, especially in the sample period 2003-2008.

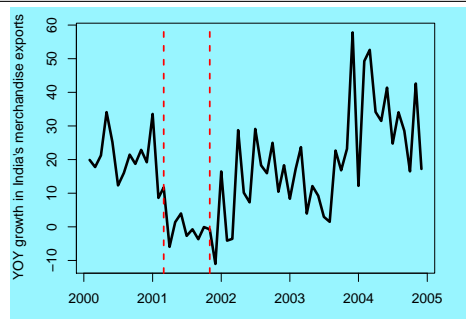
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**Figure 2** What happened in India in the US recession of 2001?

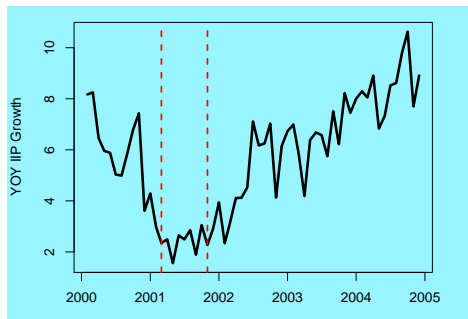
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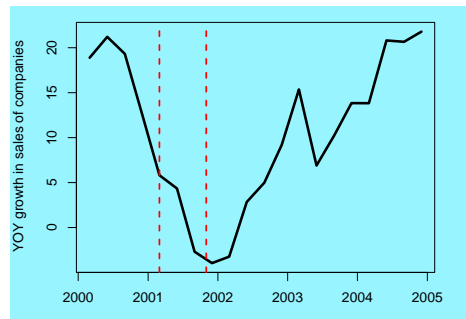
Corporate profit after tax



Merchandise exports



Industrial production growth



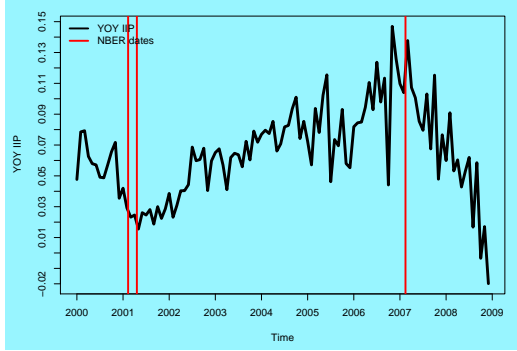
Corporate revenue growth

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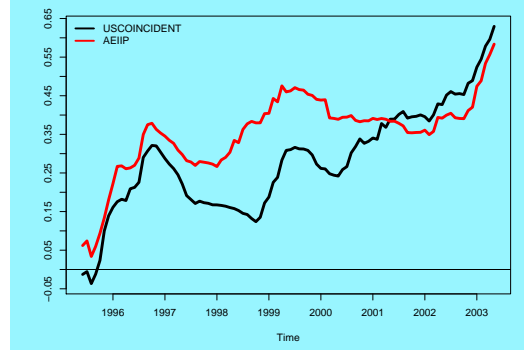
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**Figure 3** Preliminary evidence

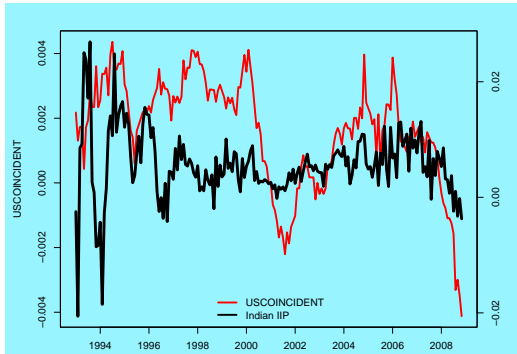
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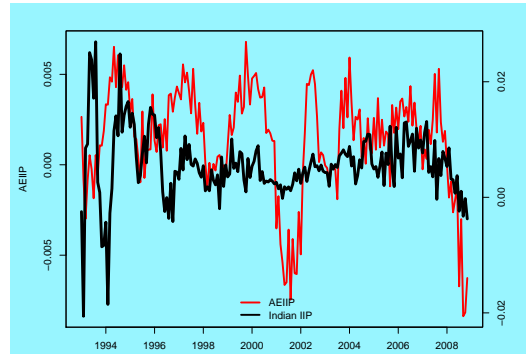
(a) Indian IIP and US recessions



(b) Rolling correlations with Indian IIP



(c) US coincident indicator & Indian IIP



(d) Advanced economies IIP & Indian IIP

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Finally, we presents rolling correlations with Indian IIP and the Indian coincident indicator across a eight-year window for the US coincident indicator and Adv. Ec. IIP. Once again, it can be seen that the correlations are increasing with time, starting from a negative value in the mid 1990's to above 0.5 post-2005.

Overall, the graphical analysis suggests that business cycles in the rest of the world show comovement and that the correlation between growth rates of IIP in India and the industrial economies (particularly the US) has been increasing over time. Section 5 now turns to a more formal analysis of this preliminary finding.

## 5 Empirical analysis

### 5.1 Methodology

There are a variety of formal methods in the literature to study business cycle synchronisation, the most popular being cross-correlations, dynamic correlations, spectral analysis and Harding-Pagan's index of concordance [Simone, 2003, Fidrmuc et al., 2008, Chan and Khong, 2007].

Following [Simone, 2003] we use the index of concordance as developed by [Harding and Pagan, 2006] as a means to test increasing business cycle synchronisation across our three sample periods. The Harding-Pagan index of concordance measures the proportion of the time that two variables are in the same state. Assuming two variables  $x$  and  $y$  over  $N$  time periods, the index of concordance between them would be:

$$I_{xy} = \frac{\#[S_{xt} = 1, S_{yt} = 1] + \#[S_{xt} = 0, S_{yt} = 0]}{N} \quad (1)$$

The value of the HP index ranges between 0-1. An index value of close to 1 would indicate perfect procyclicality while an index value of 0 would indicate perfect counter-cyclicality. However, given the markov-transition probability structure of recessions ( $Pr(S_{t+1} = 0, S_t = 0) \gg Pr(S_{t+1} = 0, S_t = 1)$ ), there is extensive serial correlation in the  $S_t$  series [Harding and Pagan, 2006]. Also, since the data duration is very short, the chances of a prolonged expansion or recession in one of the series skewing the value of the index are non-zero.

To correct for these flaws, [Harding and Pagan, 2006] demonstrate that the following relationship holds between the correlation coefficient  $\hat{\rho}_{xy}$  between  $S_x$  and  $S_y$  and  $\hat{I}_{xy}$ , which implies that the properties of  $\rho_{xy}$  are symmetric to that of  $I_{xy}$

$$I_{xy} = 1 + 2\rho_{xy}\sigma_{S_x}\sigma_{S_y} + 2\mu_{S_x}\mu_{S_y} - \mu_{S_x} - \mu_{S_y} \quad (2)$$

To estimate the correlation coefficient  $\rho_{xy}$ , we use the following OLS estimation:

$$\frac{S_{yt}}{\sigma_{S_{x_t}}\sigma_{S_{y_t}}} = A + \hat{\rho}_{xy} \frac{S_{xt}}{\sigma_{S_{x_t}}\sigma_{S_{y_t}}} + \epsilon_t \quad (3)$$

where  $\sigma_{S_{y_t}}$  denotes the standard deviation of  $S_{y_t}$ . Given that  $\epsilon_t$  inherits the serial correlation in  $S_t$ , we report Heteroskedasticity- Autocorrelation (HAC) corrected t-statistics for  $\hat{\rho}_{xy}$ <sup>7</sup>.

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<sup>7</sup>We use the Harding-Pagan turning points algorithm as implemented in the software GROCER [Dubois and Michaux, 2008]

**Table 3** Harding-Pagan Index of concordance with Indian IIP

Variable	$\hat{I}_{xy}$	$\rho \hat{S}_x \hat{S}_y$	$t$ statistic	p value
<b>Period 1: 1992-1997</b>				
US Coincident Ind.	0.536	-0.136	-0.8	0.427
Adv. Ec. IIP	0.500	-0.333	-2.629	0.011**
<b>Period 2: 1997-2003</b>				
US Coincident Ind.	0.767	0.356	1.544	0.127
Adv. Ec. IIP	0.781	0.526	2.72	0.008**
<b>Period 3: 2003-2008</b>				
US Coincident Ind.	0.781	0.501	6.438	0.000***
Adv. Ec. IIP	0.984	0.965	43.497	0.000***
<b>Full period: 1992-2008</b>				
US Coincident Ind.	0.639	0.254	2.178	0.031**
Adv. Ec. IIP	0.743	0.476	3.569	0.000***

## 5.2 Main results

The results of the Harding-Pagan analysis on the data and three sub-samples are reported in Table 3. The results support the early exploratory analysis: there is business cycle synchronisation between India and the rest of the world, and that synchronisation has increased over time.

For the full sample (1992-2008) the index of concordance suggests that Indian and US business cycles are in the same phase for 63.9% of the sample period, while cycles of industrial production in India and advanced economies are in the same phase for 74.3% of the sample. Both are statistically significant at a 95% confidence interval, and the value for the US is lower. This indicates business cycle synchronisation.

The most recent sample (2003-2008) shows stronger synchronisation. The index rose to 0.781 with the US coincident indicator, and 0.984 against advanced countries.

In Period 1 (1992-1997), the US coincident indicator and advanced economies were *negatively* correlated with Indian industrial production, suggesting that the Indian business cycle was weakly counter-cyclical to the world during this time. Also, across all samples, it can be seen that the Adv. Ec. IIP is more strongly correlated with Indian IIP, suggesting that the Indian synchronisation with industrial economies as a whole is stronger than the synchronisation with the US. In fact, for the last period 2003-2008, the the index of concordance against Adv. Ec. IIP is as high as 0.984, and it has a  $t$  statistic of 43.5.

Our results support [Calderon et al., 2007], who test for the impact of increasing trade intensity on business cycle synchronisation and find increased

correlations for countries that have closer trade ties. They are also similar to those of [Rana, 2008] who also finds increased synchronisation between East Asian economies and the rest of the world in the time period that the East Asia liberalised trade and financial policy. However, they contrast sharply with [Fidrmuc et al., 2008] who find evidence of Chinese and Indian decoupling from the OECD countries using spectral analysis.

In the following sections, we test the sensitivity of these results through a series of alternative estimation procedures.

## 6 Sensitivity tests

We present the robustness of our main results to four sets of sensitivity tests:

1. The first is the redefinition of sample periods. While we show evidence of synchronisation across time, we believe that there is no clear “begin” or “end” date for this synchronisation, rather that it is a slowly evolving phenomenon that reflects changes in the underlying structural composition of the Indian economy with respect to the rest of the world. For the analysis we change the sub-sample period dates, changing the break points to Feb-1998 and Jun-2004.
2. The second sensitivity test is done by changing the method used for analysis by detrending the data, rather than conducting growth rate cycle analysis. We have so far conducted all analysis on the trend-cyclical component of output. We now detrend the data using the Hodrick-Prescott (HP) filter, which is widely used in business cycle literature.
3. The third test is to utilise two other methodologies that are widely used for measuring comovement: cross-correlations and spectral analysis [Fidrmuc et al., 2008, Calderon et al., 2007].
4. Finally, we verify that the key results hold across redefinition of some key variables.

### 6.1 Redefining sample periods

Table 4 presents the results of the Harding-Pagan analysis for the changed sample periods. The key results hold. One difference is the value of the index of concordance for Adv. Ec. IIP in Sample 3 - it seems to have fallen considerably although it remains statistically significant at 5%.

**Table 4** Sensitivity analysis 1: Harding Pagan analysis with changed sub-samples

Variable	$\hat{I}_{xy}$	$\rho_{\hat{S}_x \hat{S}_y}$	T-Stat	P-Stat
<b>Total Sample: 1992-2008</b>				
US Coincident Ind.	0.639	0.254	2.178	0.031**
Adv. Ec. IIP	0.743	0.476	3.569	0.000***
<b>Sample 1: 1992-1998</b>				
US Coincident Ind.	0.597	-0.075	-0.451	0.654
Adv. Ec. IIP	0.565	-0.277	-2.444	0.017**
<b>Sample 2: 1998-2004</b>				
US Coincident Ind.	0.636	0.196	0.941	0.35
Adv. Ec. IIP	0.779	0.534	3.136	0.002***
<b>Sample 3: 2004-2008</b>				
US Coincident Ind.	0.453	0.277	2.325	0.024**
Adv. Ec. IIP	0.396	0.212	2.244	0.029**

## 6.2 Detrending

The Hodrick-Prescott filter is a time-domain filter that renders the resulting cyclical component stationary.<sup>8</sup> We use the Hodrick-Prescott filter with a smoothing parameter of 14400 since the data is of a monthly frequency in order to decompose the series into trend and cycle. Our empirical strategy is then repeated using the detrended data.

Table 5 reports these results. While these results cannot be directly contrasted with our main findings (this analysis tests for growth cycle synchronisation, while our main results test for growth rate cycle synchronisation), they still examine broadly the same question of synchronisation in the context of integration<sup>9</sup>.

We see that the synchronisation of business cycles in the most recent sample (2003-2008) is robust to the HP filter. However, there are two notable differences in the results obtained. First, the world variable Adv. Ec. IIP is not significantly synchronised with Indian IIP across the total sample 1992-2008. Second, the HP filter finds that there is no statistically significant synchronisation in the period 1992-1997. This agrees with evidence of negative synchronisation in this period.

<sup>8</sup>Criticisms of the HP filter include spurious cycles, phase shifts in the variables and a high level of sensitivity of results [Canova, 1998, Harvey and Jaeger, 1993].

<sup>9</sup>See Harding and Pagan [2002] for an overview of the differences between growth and growth rate cycles



**Table 5** Sensitivity analysis 2: Harding-Pagan analysis with HP-filtered IIP series

Variable	$\hat{I}_{xy}$	$\rho_{\hat{S}_x \hat{S}_y}$	T-Stat	P-Stat
<b>Total Sample: 1992-2008</b>				
US Coincident Ind.	0.629	0.242	1.672	0.096*
Adv. Ec. IIP	0.599	0.238	1.595	0.112
<b>Sample 1: 1992-1997</b>				
US Coincident Ind.	0.41	0.116	0.843	0.402
Adv. Ec. IIP	0.328	-0.186	-0.766	0.447
<b>Sample 2: 1997-2003</b>				
US Coincident Ind.	0.904	0.758	12.618	0.000***
Adv. Ec. IIP	0.507	0.218	1.762	0.082*
<b>Sample 3: 2003-2008</b>				
US Coincident Ind.	0.954	0.776	6.445	0.000***
Adv. Ec. IIP	0.862	0.243	1.775	0.081*

### 6.3 Static and dynamic correlations

We now examine two other methodologies for checking comovement - cross-correlations and spectral analysis. Both are widely used in the literature [Fidrmuc et al., 2008, Calderon et al., 2007] and the results confirm our key findings. Cross-correlations at lag -1, 0 and 1 for each world variable with respect to Indian IIP have substantially increased over the period 1992-2008, and so has spectral coherence (also called dynamic correlation) over growth rate cycle frequencies. Appendix A.1 and A.2 report our findings and methodology in greater detail.

### 6.4 Redefining key variables

For the final sensitivity test, we redefine our measure of US business cycles from the US coincident indicator to the Index of Industrial Production in the US. In a similar vein, we use a measure of total world trade (exports plus imports), as a proxy for Adv. Ec. IIP<sup>10</sup>. The results are reported in Table 6.

It can be seen that all results hold with respect to the variable measuring world trade, but there is a fall in the statistical significance of USIIP both in the total sample and in the third period (2003-2008).

<sup>10</sup>Export and import data is sourced from the IMF-IFS, and expressed in USD billion. US IIP is sourced from the St. Louis Federal Reserve Database (FRED). Both variables are adjusted for seasonal fluctuations.

**Table 6** Sensitivity analysis 3: Harding-Pagan analysis, redefining key variables

Variable	$\hat{I}_{xy}$	$\rho\hat{S}_x\hat{S}_y$	T-Stat	P-Stat
<b>Total Sample: 1992-2008</b>				
USIIP	0.516	0.048	0.353	0.724
WORLDTRADE	0.705	0.397	3.014	0.003***
<b>Sample 1: 1992-1997</b>				
USIIP	0.375	-0.064	-0.266	0.791
WORLDTRADE	0.536	-0.299	-2.57	0.013**
<b>Sample 2: 1997-2003</b>				
USIIP	0.781	0.548	2.966	0.004***
WORLDTRADE	0.795	0.509	2.893	0.005***
<b>Sample 3: 2003-2008</b>				
USIIP	0.429	0.123	0.913	0.365
WORLDTRADE	0.841	0.698	7.282	0.000***

## 7 Conclusion

In this paper, we find that the Indian business cycle is synchronised with that of the US and other industrial economies. We also find that this synchronisation has increased across time in the period 1992-2008, i.e. the period that saw a significant rise in India's trade and capital flows. Finally, the linkages of the Indian economy are stronger when measured against a broad set of industrial countries as opposed to just the US.

This paper contributes to the evolving empirical evidence on the question of whether emerging market economies such as India are decoupled with industrial economies or not. As there is no consensus in the literature, and business cycles in India have emerged as an important part of the debate, the paper is an important contribution as it strongly supports the evidence that business cycles in India are coupled with those in industrial countries and that this coupling has been increasing with India's greater globalisation.

This paper focussed on establishing business cycle synchronisation. It did not attempt to study the transmission mechanism and causal relationships through which business cycle synchronisation takes place. Second, it analysed only output fluctuations to study comovement of cycles. Future research would need to analyse other variables as well as study the transmission mechanism of comovements.

## References

- Pierre-Richard Agenor, C John McDermott, and Eswar S Prasad. Macroeconomic fluctuations in developing countries: Some stylized facts. *World Bank Economic Review*, 14(2):251–85, May 2000.
- Mark Aguiar and Gita Gopinath. Emerging market business cycles: The cycle is the trend. *Journal of Political Economy*, 115:69–102, 2007.
- Ç. Akin and M.A. Kose. Changing nature of North–South linkages: Stylized facts and explanations. *Journal of Asian Economics*, 19(1):1–28, 2008.
- M. Baxter and M.A. Kouparitsas. Determinants of business cycle comovement: a robust analysis. *Journal of Monetary Economics*, 52(1):113–157, 2005.
- Cesar Calderon, Alberto Chong, and Ernesto Stein. Trade intensity and business cycle synchronization: Are developing countries any different? *Journal of International Economics*, 71(1):2–21, March 2007.
- Fabio Canova. Detrending and business cycle facts. *Journal of Monetary Economics*, 41(3):475–512, May 1998.
- Tze-Haw Chan and Wye Leong Roy Khong. Business cycle correlation and output linkages among the Asia-Pacific economies. MPRA Paper 11305, University Library of Munich, Germany, December 2007.
- Vikas Chitre. Indicators of business recessions and revivals in india: 1951-1982. *Indian Economic Review*, 36(1):79–105, January 2001.
- Zsolt Darvas and Gyrgy Szapry. Business cycle synchronization in the enlarged EU. *Open Economies Review*, 19(1):1–19, February 2008.
- Pami Dua and Anirvan Banerji. Business cycles in india. Working papers 146, Centre for Development Economics, Delhi School of Economics, August 2006.
- Eric Dubois and Emmanuel Michaux. Grocer 1.3: An econometrics toolbox for Scilab, 2008.
- Jarko Fidrmuc, Iikka Korhonen, and Ivana Btorov. China in the world economy: Dynamic correlation analysis of business cycles. BOFIT Discussion Papers 7/2008, Bank of Finland, Institute for Economies in Transition, June 2008.
- Jeffrey A Frankel and Andrew K Rose. The endogeneity of the optimum currency area criteria. *Economic Journal*, 108(449):1009–25, July 1998.

- Don Harding and Adrian Pagan. Dissecting the cycle: A methodological investigation. *Journal of Monetary Economics*, 49(2):365–381, March 2002.
- Don Harding and Adrian Pagan. Synchronization of cycles. *Journal of Econometrics*, 132(1):59–79, May 2006.
- A C Harvey and A Jaeger. Detrending, stylized facts and the business cycle. *Journal of Applied Econometrics*, 8(3):231–47, July-Sept 1993.
- Alessandra Iacobucci. Spectral analysis for economic time series. Documents de Travail de l’OFCE 2003-07, Observatoire Francais des Conjonctures Economiques (OFCE), 2003.
- DL Kohn. Global Economic Integration and Decoupling. Speech at the International Research Forum on Monetary Policy, Frankfurt, Germany, June, 2008.
- M. Ayhan Kose and Kei-Mu Yi. International trade and business cycles: Is vertical specialization the missing link? *American Economic Review*, 91(2):371–375, May 2001.
- M. Ayhan Kose, Eswar S. Prasad, and Marco E. Terrones. How does globalization affect the synchronization of business cycles? *American Economic Review*, 93(2):57–62, May 2003.
- M.A. Kose, C. Otrok, E. Prasad, International Monetary Fund, and Research Dept. *Global Business Cycles: Convergence or Decoupling?* National Bureau of Economic Research Cambridge, Mass., USA, 2008.
- Paul Krugman. *The Transition to Economic and Monetary Union in Europe*, chapter Lessons of Massachusetts for EMU, pages 241–261. Cambridge University Press, 1993.
- Masanaga Kumakura. Trade and business cycle co-movements in asia-pacific. *Journal of Asian Economics*, 17(4):622–645, October 2006.
- O P Mall. Composite index of leading indicators for business cycles in india. Technical Report 3, Reserve Bank of India, 1999.
- Fabio Moneta and Rasmus Ruffer. Business cycle synchronisation in east asia. *Journal of Asian Economics*, 20(1):1–12, 2009.
- Ila Patnaik. India’s experience with a pegged exchange rate. In Suman Bery, Barry Bosworth, and Arvind Panagariya, editors, *The India Policy Forum 2004*, pages 189–226. Brookings Institution Press and NCAER, 2005.
- Ila Patnaik. India’s currency regime and its consequences. *Economic and Political Weekly*, March 2007.

- Ila Patnaik and Rachna Sharma. Business cycles in the Indian economy. *Margin*, 35(1):71–79, 2002.
- Eswar S Prasad. International trade and the business cycle. *Economic Journal*, 109(458):588–606, October 1999.
- R Development Core Team. *R: A language and environment for statistical computing*. R Foundation for Statistical Computing, Vienna, Austria, 2005. ISBN 3-900051-07-0.
- Pradumna B. Rana. Trade intensity and business cycle synchronization: The case of East Asian countries. *The Singapore Economic Review (SER)*, 53(02): 279–292, 2008.
- RBI. Leading indicators for the Indian economy. Technical report, Reserve Bank of India, 2006.
- Kwanho Shin and Yunjong Wang. Trade integration and business cycle synchronization in east asia. *Asian Economic Papers*, 2(3):1–20, 2003.
- Francisco Nadal-De Simone. Common and idiosyncratic components in real output: Further international evidence. IMF Working Papers 02/229, International Monetary Fund, January 2003.

# A Appendix

## A.1 Cross-correlations

Cross-correlations are the simplest and most commonly used method to analyse comovements between series. Despite their static nature, they provide two sources of insight into comovements. The level of the correlation indicated the strength of comovements. The nature of pro/counter cyclicity of the variable is indicated by the sign - a positive sign indicates counter-cyclicity while a negative sign indicates procyclicality. A value of zero indicates that the variable is acyclical.

We present below cross-correlations of various lags of the US coincident indicator and Adv. Ec. IIP with the Indian IIP (INIIP). It can be seen that as we move across samples, the correlations switch signs from negative to positive. They also increase considerably in magnitude and statistical significance, with all correlations in Sample 3 (2003-2008) being significant at 1%. Confidence intervals at 95% are calculated using sample covariances.

**Table 7** Cross-correlations with Indian IIP

Variables	t-4	t-3	t-2	t-1	t	t+1	t+2	t+3	t+4
<b>Total sample: 1992-2008</b>									
Indian IIP	0.01	0.22**	0.48***	0.57***	1.00***	0.57***	0.48***	0.22**	0.01
US Coincident Ind.	0.14	0.15*	0.17*	0.19**	0.20**	0.22**	0.18**	0.19**	0.15*
Adv. Ec. IIP	0.20**	0.20**	0.21**	0.21**	0.24***	0.19**	0.18**	0.10	0.10
<b>Sample 1: 1992-1997</b>									
Indian IIP	-0.13	0.15	0.45***	0.61***	1.00***	0.61***	0.45***	0.15	-0.13
US Coincident Ind.	-0.02	-0.15	-0.08	-0.07	-0.04	0.02	0.00	0.09	-0.07
Adv. Ec. IIP	0.15	0.13	-0.01	-0.01	0.01	-0.06	-0.13	-0.30*	-0.26
<b>Sample 2: 1997-2003</b>									
Indian IIP	0.21	0.21	0.39***	0.29**	1.00***	0.29**	0.39***	0.21	0.21
US Coincident Ind.	0.07	0.14	0.20	0.25*	0.26*	0.30**	0.29**	0.29**	0.30**
Adv. Ec. IIP	0.16	0.27*	0.35***	0.46***	0.48***	0.46***	0.52***	0.49***	0.47***
<b>Sample 3: 2003-2008</b>									
Indian IIP	0.32**	0.27**	0.45***	0.37***	1.00***	0.37***	0.45***	0.27**	0.32**
US Coincident Ind.	0.37***	0.47***	0.44***	0.54***	0.56***	0.56***	0.44***	0.38***	0.35***
Adv. Ec. IIP	0.36***	0.31**	0.50***	0.45***	0.55***	0.41***	0.45***	0.36***	0.33***

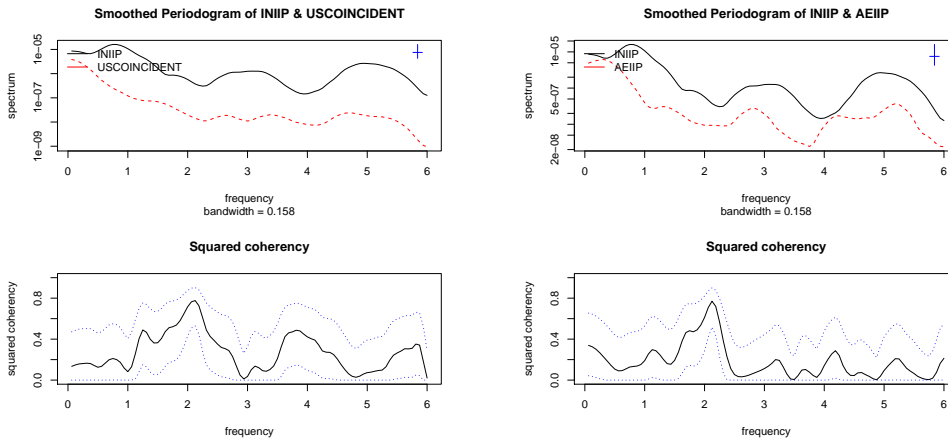
## A.2 Spectral analysis

Spectral analysis provides a frequency domain complement to cross-correlation analysis, with the advantages of being able to decompose comovements into those at short, medium and long term frequencies. However, as we are studying growth rate cycles, we must keep in mind that differencing is an asymmetric frequency operation and may lead to the introduction of high frequency components [Iacobucci, 2003]. Moreover, since our data duration is short (197 observations across 16 years of monthly data), spectral estimations may be biased. In spite of these limitations, a frequency domain perspective does provide further insight into business cycle comovements. First, we present cross-spectral periodograms (See Figure 4). Periodograms are estimated via a Discrete Fast Fourier Transformation, and then smoothed with a modified Daniell filter to generate the periodogram with scaled densities.

Second, we report spectral coherence, a frequency domain analogue to the correlation coefficient. It is calculated as per Equation 4 where  $S_1(k)$  is the spectral periodogram of Variable 1 at frequency  $k$ ,  $S_2(k)$  is that of variable 2 and  $S_{12}(k)$  is their cross-spectrum. Based on growth rate cycle periodicities (roughly between 12-24 months), low frequencies are identified as those with 0.5 or less cycles per year, mid-range as those between 1 to 0.5 cycles per year and high greater than 1 cycle per year.

$$\hat{K}_{12}(k) = \frac{\hat{S}_{12}(k)}{\sqrt{\hat{S}_1(k)\hat{S}_2(k)}} \quad (4)$$

**Figure 4** Cross-spectral analysis between Indian IIP and world variables



(a) Indian IIP & US coincident indicator

(b) Indian IIP & Adv. Ec. IIP

**Table 8** Spectral coherence with Indian IIP

Variable	Coherence		
	Low freq	Mid freq	High freq
<b>Total Sample: 1992-2008</b>			
Indian IIP	1.00	1.00	1.00
US coincident indicator	0.02	0.12	0.08
Adv. Ec. IIP	0.21	0.11	0.19
<b>Sample 1: 1992-1997</b>			
Indian IIP	1.00	1.00	1.00
US coincident indicator	0.07	0.04	0.04
Adv. Ec. IIP	0.03	0.02	0.06
<b>Sample 2: 1997-2003</b>			
Indian IIP	1.00	1.00	1.00
US coincident indicator	0.08	0.18	0.15
Adv. Ec. IIP	0.05	0.64	0.35
<b>Sample 3: 2003-2008</b>			
Indian IIP	1.00	1.00	1.00
US coincident indicator	0.10	0.69	0.51
Adv. Ec. IIP	0.26	0.68	0.42

It can be seen that both sets of results indicate business cycle synchronisation, and the mean coherence estimates over the three sub-samples indicate that this synchronisation has been increasing over time. Following RBI [2006], we consider a coherence of greater than 0.30 as an indication of significant comovement. It can be seen that the coherence at the mid-range frequencies over the period 2003-2008 are 0.69 and 0.68 respectively, and that coherence across this range of frequencies has been increasing over the period 1992-2008.