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CAPACITY OUTPUT AND CYCLES IN NON-AGRICULTURAL OUTPUT IN THE INDIAN ECONOMY[1]

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Abstract

We estimate capacity output and cycles relative to it in India's non-agricultural sector from 1951 to 2008, defining capacity as the level of output beyond which demand leads to a rise in prices. We postulate a delayed response of the price level of non-agricultural goods and services after demand exceeds capacity output, and use a VAR involving growth rate of non-agricultural output and inflation to estimate underlying structural demand and supply shocks. We estimate the structural parameters of the model, treating them as unknown polynomial functions of the lag operator rather than as scalars. We identify nine cycles in India's non-agricultural output. Capacity utilisation in non-agricultural sector, while showing the above-mentioned cycles, has declined till 1979 and increased thereafter.

Keywords: Capacity Output, Capacity Utilisation, Output Gap, Trends and Cycles, Business Cycles, Growth Cycles in Indian Economy, Blanchard-Quah De-composition, Estimation of Demand and Supply Shocks, Growth and Inflation, Structural VAR, Estimation of Structural Parameters from VAR, Estimation of Structural Parameters as Polynomial Functions of Lag Operators.

JEL Classification: C 22, C32, E22, E 31, E32, N15.

1. Introduction

The question, which I have chosen to address in this paper, is the challenging one of separating the trends and the cycles in Indian economy. This question acquires critical

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significance for policy formulation as well from time to time as it is critical to know whether the economy is currently operating above or below its potential. Since we shall characterise potential output as corresponding to full capacity output defined as the level of output beyond which an increase in demand begins to raise the prices of non-agricultural goods and services, in the process of our analysis, we shall also achieve the separation of demand pull and cost push factors behind inflation from time to time and an estimation of capacity output.

Specifically, I shall attempt to separate the trend from the cyclical component of the Gross Domestic Product at constant prices originating in the non-agricultural sector of India. But the method of analysis should be applicable in other similar situations. Also, I shall analyze the annual data here but the method may probably be even more suitable, of course with appropriate modifications, to relevant quarterly or monthly time series.

The main inspiration of the present work is the seminal paper on the subject by Olivier Blanchard and Danny Quah, published in *American Economic Review* in September 1989. I do, however, hope to take the discussion further, by using a model, which introduces some specifications in the context of growth, apart from being more relevant for a developing economy such as that of India.

Following the publication of the seminal paper by Nelson and Plosser (1982), on Trends and Random Walks in Macroeconomic Time series, it is by now well-known that for most macroeconomic time series, not only for the United States, but also for other countries, including India, it is not possible to reject the hypothesis that these series are non-stationary stochastic processes that have no tendency to return to a deterministic trend line. They are difference-stationary rather than trend-stationary. They are not covariance-stationary. Thus, most macroeconomic time series show stochastic, rather than deterministic, trends. That is, the means of their forecasts, over a future period, change (generally increase) with the period of the forecast and are influenced by the initial conditions. Moreover, the variances of the forecast errors increase in proportion to the square of the period of the forecast, thus correctly reflecting the increasing uncertainty surrounding future forecasts as the period of the forecast is extended further into the future. For these series, the serial correlations at different time lags also depend on the length of the lag considered.

It has been further shown by Nelson and Kang (*Econometrica*, May 1981) that while de-trending a trend stationary time series by estimating the underlying trend through regression produces an unbiased estimate of the stationary component, similarly de-trending a difference stationary series produces residuals which are not stationary but which nevertheless show spurious periodicity.

Gonzalo and Granger (1995) suggest a decomposition of difference stationary time series into permanent and transitory components by using the error correction model formulation of such time series. But that decomposition is based on the characterisation of the two components wherein only the innovations in the permanent component can Granger-cause or govern the future course of the permanent component and the innovations in the transitory component cannot affect the expected value of the permanent component in future in the long run. While such characterisation may be useful in other contexts (e.g. to delineate permanent and transitory components of income as characterised by Milton Friedman, with the correlation between the two to be zero), it may not be properly applicable in the context of separating the trend and cyclical components, as the latter are quite often likely to influence the future trend (or capacity levels) of output, for example through what happens to investment during the course of the cycle.

The key idea used in the Blanchard – Quah paper is to consider together in a Vector Auto Regression model, two series, the first difference of real GNP and the rate of unemployment, both of which are stationary, and to use a condition that demand shocks have no long-run effect on real GNP, while supply shocks have a permanent effect on it, in order to identify and separate the two shocks. Both shocks are assumed to have only temporary effects on the rate of unemployment as postulated under the natural rate hypothesis under the assumption of nominal wage flexibility. Having identified the demand and supply shocks, they show that the simulated real GNP and the rate of unemployment, obtained through the impulse responses to the identified demand shocks, setting the supply shocks to be zero, “match closely” the reference cycles identified by the National Bureau of Economic Research. The simulated behavior of real GNP, again through the estimated impulse response function in response to the identified supply shocks, with all demand shocks set to zero, then shows the upward movement of real GNP in response to the supply shocks, which reflects the permanent effect of supply shocks on output.

While modifying the Blanchard - Quah model to identify the demand and supply shocks in the context of India and then to separate the cyclical component of the GDP originating in non-agricultural sector, we may note the following three points. First, the Blanchard - Quah formulation ignores the long term effect of demand on output via increase in productive capacity through investment. This also leads to neglecting the interdependence between the cycle and the trend, which may be important even in the context of the developed economies. Secondly, Blanchard and Quah incorporate the natural rate hypothesis in their model, by means of a wage – setting equation, which reflects nominal wage rigidity by assuming that the nominal wage is set at a level expected to clear the labour market during the next period. This may need to be substituted, particularly as far as the non-agricultural sector of a developing country like India is concerned, instead, by an equation relating the price level for goods and services produced in the non-agricultural sector. Such a formulation also avoids using the level of unemployment as a variable, for which a satisfactory time series would be difficult to compile.

2. The Model

The variant of the Blanchard-Quah model, incorporating the above points, which we shall use, is given below:

$$Y(t) = b\big(M(t) - P(t)\big) + a\theta(t) \qquad \text{(Aggregate Demand)} \qquad \dots (1)$$

$$\overline{Y}(t) = K(t) + \theta(t) \qquad \text{(Capacity Output)} \qquad \dots (2)$$

$$P(t) = \alpha(Y(t-1) - \overline{Y}(t-1)) - \theta(t) \qquad \text{(Aggregate Supply/Price Setting)} \qquad \dots (3)$$

$$K(t) = K(t-1) + \big[1 + i(t-1)\big] \qquad \text{(Capital Stock Adjustment)} \qquad \dots (4)$$

$$\big[1 + i(t-1)\big] = \beta_0 + \beta_1 Y(t-1) + \beta_2(t-2)Y(t-2) + \dots\dots. \qquad \text{(Investment function)} \qquad \dots (5)$$

$$M(t) = M(t-1) + e_d(t) \qquad \text{(Money Stock)} \qquad \dots (6)$$

$$\theta(t) = \theta(t-1) + e_s(t) \qquad \text{(Productivity)} \qquad \dots (7)$$

Here Y(t),Ÿ(t), K(t), and P(t) are the logarithms, respectively of output, capacity output, capital stock, price level of the goods and services produced in the non-agricultural sector, M(t) and θ(t) are the logarithms, respectively of the money stock and productivity. i(t) is the rate of net investment in the non-agricultural sector [1 + i(t)] is to be read as the logarithm of (1 + the rate of net investment) as we have dropped the notation for logarithm.

Equation (1) gives that aggregate demand is influenced by real balances, (expressed in terms of the goods and services produced in the non-agricultural sector) and productivity. In fact, real balances should have been measured in terms of the full commodity basket, consisting of both agricultural and non-agricultural commodities. However, we have not explicitly introduced the price level of agricultural commodities, implicitly assuming that the effect on demand for non-agricultural commodities due to changes in this relative price are included in the last term in equation (1) giving the effect of productivity on aggregate demand. We shall comment on this assumption at the end of the paper highlighting the limitation implied by this assumption.

Equation (2) is the equation for capacity output. Capacity is assumed to be constrained by capital stock and not labour. Output is assumed to be determined by demand. Output, in turn, determines employment, which we shall not focus upon here.

Equation (3) for the price level of non-agricultural goods and services introduces the idea that the price *level* is determined by the output gap and productivity. This is a departure from the usual specification where the *change* in the price level is related to the output gap. In our formulation, if output is at the capacity level, the equilibrium price level will be governed by productivity and the variation in it will reflect changes in productivity. The formulation introduced here is motivated by the empirical observation, to be noted presently, that the rate of inflation (or, more strictly the rate of change) in the price level of non-agricultural commodities is stationary though the price level itself is non-stationary.

In writing equation (3) for price adjustment we have made the critical assumption of the present paper that the price level of non-agricultural goods and services responds to demand after a lag of one period but responds immediately to supply shocks. This assumption takes the place of the condition imposed by Blanchard and Quah that demand shocks do not have any long-term effect on output. Thus, we permit both demand and supply shocks to have an effect on output in the long run but, instead, we introduce short-run stickiness of the prices of non-agricultural goods and services in response to changes in demand. The non-agricultural sector may be viewed as being dominated by monopolistically competitive and oligopolistic firms. These firms are likely to respond quickly to changes in input prices and marginal costs originating in supply side shocks. But they may take time in assessing whether changes in demand are permanent or temporary, or general or product specific, and may also require taking into account competitors' probable actions, before revising prices of their products. In addition, prevalence of implicit or explicit contracts and administered prices may also lead to short-run stickiness in prices. While the unorganised manufacturing sector would include a multitude of producers in most of its sub-sectors still a delayed price response to excess of demand over capacity (whenever it occurred) does not seem to be an unrealistic assumption. Where the sub-sectors were dominated by skilled producers in short supply (such as carpenters or plumbers) possibly the assumption may not hold good during a period as long as one year. While retail trade in the formal sector would be characterised by delayed response in the pricing of the trading services on account of oligopolistic competition, retail trade in the informal sector, particularly in the urban and semi-urban areas, would also show delayed increases in trading margins in response to demand pressures because of monopolistic competition. Professional services which are characterised by relatively long duration customer relationships are also likely to show tardy adjustment in professional fees Delayed price response to changes in demand by public or private providers of services is also subsumed in this assumption. Public services as well as private services in the non-agricultural sector as a whole include sectors such as electricity, water supply, education and health services, transport and communication and public administration. Delayed decisions to increase prices of the services in response to increase in demand in excess of capacity are likely to be common in these sectors. This assumption enables us to identify and separate the underlying unobserved demand and supply shocks. It may be clarified that we assume that capacity output and price level responds to supply changes during the current period. However, since we shall, in what follows, interpret the response parameter α in equation (3) not as a scalar but as a polynomial in the lag operator and thus it yields a distributed lag function of the output gap, it is sufficient for our purpose that all price response to changes in demand and output gap is delayed by at least one period *and may be spread over a few years following that.*

We are postulating that price response would be delayed by one period. A quarter would have perhaps better measured this period than a year.[3] We chose to work with annual data in the present paper for two reasons: (i) Annual GDP series extend far back in history to provide cycle estimates with the present new method for comparison with the findings about growth cycles from the earlier period based on earlier work on the subject, based on annual data; and (ii) Estimates of quarterly data on GDP originating in agriculture and in the non-agricultural sector are subject to limitations about measuring agricultural output during the quarters.

Equation (4) shows how capital stock is accumulated through net investment. K(t) is the logarithm of the stock of capital *at the beginning* of t^{th} period. The strange looking formulation of this equation and correspondingly of the investment function, specified in equation (5), had to be introduced because K(t) is the logarithm of capital stock and not capital stock itself. i(t-1) is the rate of *net* investment in period (t-1), given by the ratio of net investment to capital stock (*not* to the logarithm of capital stock to be sure) at the beginning of period (t-1). The investment function, specified in equation (5), uses a simple formulation that [1 + i(t)] is determined by the logarithms of past outputs (or, in an alternative formulation referred to in footnote 1 by the logarithms of past output-capital ratios). Repeated substitutions for [1 + i(t-1)], [1 + i(t-2)], etc. (and for K(t-1), K(t-2), etc. in the alternative formulation), give the simpler formulation appearing in equation (5).

Here, the constant β_0 represents autonomous investment, i.e., the part of net investment which is not influenced by current or past output levels (or, in the alternative formulation, current and past output-capital ratios, to reflect the levels of output relative to capacity or the profitability of the non-agricultural sector, or both). The crucial importance of β_0 and hence of autonomous investment, in the context of the present paper is that its presence introduces a deterministic

3 Carlton (1986) which studied price rigidity of 32 specific intermediate products in US manufacturing sector for the period from January 1, 1957 to December 31, 1966, had reported that of these 20 products had average duration of price rigidity spells of longer than 12 months and all longer than a quarter, whereas 22 products had average duration of price rigidity between transactions longer than 12 months and all longer than a quarter. I am not aware of any similar study for a more recent period, or for a wider set of commodities, or for India.

trend in the logarithm of capacity output, as will become clear presently from equation (8) below, and hence, in actual output and the price level. If there has to be a deterministic trend in the logarithm of GDPNA and the logarithm of GDPNADEF, the two are integrated of order 1 but not cointegrated, as per the statistical tests reported below. In that case, a simple VAR model involving the first differences in them, i.e. dlngdpna and dlngdpnadef is appropriate for our analysis, and we do not need to use a Vector Error Correction (VEC) model.

Equation (6) presents the stochastic process governing money stock and equation (7) the stochastic process governing productivity. $e_d(t)$ and $e_s(t)$ are interpreted as the demand and supply shocks, respectively. They are both assumed to have zero means and finite variances σ_d^2 and σ_s^2, are non-auto correlated and are not correlated with each other. As has been clarified by Blanchard and Quah (1989, p.656), if the demand and supply shocks happen to be auto-correlated, then as long as the stochastic processes governing them are dynamically stable, each of them can, in turn, always be uniquely expressed as invertible lag function of serially uncorrelated disturbances. We can then refer to the serially uncorrelated disturbances as demand and supply shocks.

A few examples of the supply and demand shocks may be considered here to bring out the nature, plausibility, implications and limitations of the assumptions made here. A good harvest of agricultural raw materials such as sugarcane or cotton reducing their prices would be a favourable supply shock in the non-agricultural sector and is assumed to lead to increased output and lower prices of non-agricultural goods during the same year. An enhanced output of wage goods has similar favourable supply side effects on non-agricultural output and/or prices, through their effects on wage costs. Thus, although we focus attention here on the cycles in GDP originating in non-agricultural sector because the cycles in agricultural production are most likely to be due to weather fluctuations and are exogenous, the effects of the latter on the former through the various well-known transmission mechanisms, such as through the availability of agricultural raw materials and wage goods, consumption and investment demand for non-agricultural goods and services and the agriculture non-agriculture terms of trade, are not ignored here. To consider more examples of the demand and supply shocks, an increase in oil prices increasing the cost of production in the non-agricultural sector would be an adverse supply shock resulting in an adverse effect on output and/or an increase in the prices of non-agricultural goods. If the government does not allow a full transmission of the oil price rise to the users, then the supply shock is modified to a corresponding extent. The income effects of these shocks lead to demand effects, which are reflected in the coefficient a in equation (1). If the oil subsidy increases the government's fiscal deficit, the consequent interest rate effects on demand also have to be assumed to be reflected in the coefficient a in equation (1), so that the demand and supply shocks themselves can be assumed to be uncorrelated. The money stock variable in equation (6) may be viewed as a very broad measure of nominal money stock or liquidity in the economy, influencing aggregate demand. Money stock expansion by monetary authority would constitute a positive demand shock. Increased inflow of funds from abroad not neutralised by monetary authority would be an example of demand shock. Since, in the present exercise, the money stock variable is eliminated through substitution, it does not feature in the vector auto regression exercise reported here. Therefore, if one does not want to accept a purely monetarist interpretation of the demand shock, one may replace M (t) in equation (6) by say D(t) = D (M(t), A(t)) (= Ln (b_0 +b_1M(t)+b_2 A(t)) for the usual linear IS-LM model) giving logarithm of *nominal* aggregate demand which is an appropriate function of *nominal* autonomous expenditure and money stock. Changes in nominal autonomous government expenditure, autonomous investment, or net exports may now be viewed as creating demand shocks. If changes in indirect taxes or business taxes or changes in exchange rates have simultaneously large effects on aggregate demand and the costs of production of producers, they could create difficulties for the assumption of the demand and supply shocks being contemporaneously uncorrelated. Also, a critical difference between the demand and supply shocks in the present formulation which now becomes clear is that while the former is a nominal shock the latter is a real shock.

$$K(t) = K(0) + [1 + i(0)] + [1 + i(1)] + ...$$

$$= K(0) + \gamma_0 t + \sum_{k=1}^{t} \gamma_k Y(t-k)$$

where $\gamma_k = \sum_{j=1}^{k} \beta_j$ and $\gamma_0 = \beta_0$

Therefore, $\bar{Y}(t) = K(0) + \gamma_0 t + \sum_{k=1}^{t} \gamma_k Y(t-k) + \theta(t)$ … (8)[4]

We observe from equation (5) that K(t) can be written as:

From the model presented in equations (1) - (7) and using equation (8), we can immediately derive equations for changes in our key variables:

$$\Delta Y(t) = -b\Delta P(t) + b\, e_d(t) + a\, e_s(t) \quad \text{… (9)}$$

$$\Delta \bar{Y}(t) = \gamma_0 + \sum_{k=1}^{t} \gamma_k \, \Delta Y(t-k) + e_s(t) \quad \text{… (10)}$$

$$\Delta P(t) = \alpha(\Delta Y(t\text{-}1) - \Delta \bar{Y}(t-1)) - e_s(t) \quad \text{… (11)}$$

Or, using the lag operator L,

$$\Delta Y(t) = -b\Delta P(t) + b\, e_d(t) + a\, e_s(t) \quad \text{… (12)}$$

$$\Delta \bar{Y}(t) = \gamma_0 + \Gamma(L)\Delta Y(t) + e_s(t) \quad \text{… (13)}$$

$$\Delta P(t) = \alpha L[\Delta Y(t) - \Delta \bar{Y}(t)] - e_s(t) \quad \text{… (14)}$$

Where the polynomial $\Gamma(L)$ is given by

$$\Gamma(L) = [\gamma_1 + \gamma_2 L + \gamma_3 L^2 + ...]L \quad \text{… (15)}$$

The above system can be solved to yield the following solutions for ΔY(t) and ΔP(t) :

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4 If net investment is postulated to depend on current and past output capital ratios rather than only on the current and past output levels, it can be checked that equation (8) still continues to be valid, except that the definitions of the parameters γk , appearing in it, are modified as given below:

$\gamma_0 = \beta_0 \,(1 - \Sigma_1^{t} \beta_j)$ and $\gamma_k = (\Sigma_1^{k} \beta_j - \Sigma_1^{k-1} \beta_j \,(\Sigma_1^{k-j} \beta_j))$

$$\Delta P(t) = \alpha L(1-\Gamma(L))[\alpha b \gamma_0 (1+\alpha bL(1-\Gamma(L))]^{-1} + \alpha bL(1-\Gamma(L))[1+\alpha bL(1-\Gamma(L))]^{-1} e_d(t)$$
$$+ \alpha aL(1-\Gamma(L))[1+\alpha bL(1-\Gamma(L))]^{-1} e_s(t) + \alpha bL(1-\Gamma(L))(1-\alpha L)[1+\alpha b(1-\Gamma(L))]^{-1} e_s(t) \quad \ldots (16)$$
$$-(1-\alpha L)\, e_s(t)$$

and

$$\Delta Y(t) = \alpha b\, \gamma_0 \, [1+\alpha bL(1-\Gamma(L))]^{-1} + b[1+\alpha bL(1\text{-}\Gamma(L))]^{-1} e_d(t)$$
$$+ a[1+\alpha bL(1\text{-}\Gamma(L))]^{-1} e_s(t) + b(1-\alpha L)[1+\alpha bL(1\text{-}\Gamma(L))]^{-1} e_s(t) \quad \ldots (17)$$

For deriving equations (16) and (17), we assume that the stochastic difference equation for ΔY(t) obtained by substituting equation (11) into equation (13) and then substituting equation (13) in turn in equation (12), has a stable solution, that is its characteristic roots lie inside the unit circle. This allows us to write $[1+\alpha bL(1-\Gamma(L))]^{-1}$.

Ignoring the constant terms in the above two equations and considering the dynamic part of the solutions, we can write the impulse - response functions in matrix notation, as given in equation (18):

$$\begin{bmatrix} \Delta Y(t) \\ \\ \Delta P(t) \end{bmatrix} = \begin{bmatrix} b[1+\alpha bL(1-\Gamma(L))]^{-1} & a[1+\alpha bL(1-\Gamma(L))]^{-1} \\ & + b(1-\alpha L)[1+\alpha bL(1-\Gamma(L))]^{-1} \\ \alpha L(1-\Gamma(L))\, b[1+\alpha bL(1-\Gamma(L))]^{-1} & a\alpha L(1-\Gamma(L))[1+\alpha bL(1-\Gamma(L))]^{-1} \\ & + b\alpha L(1-\Gamma(L))[1-\alpha L][1+\alpha bL(1-\Gamma(L))]^{-1} \\ & -(1-\alpha L) \end{bmatrix} \times \begin{bmatrix} e_d(t) \\ \\ e_s(t) \end{bmatrix} \quad \ldots (18)$$

The following observations may be made on the basis of the impulse response matrix:

1. It can be checked that both ΔY(t) and ΔP(t) are stationary, under the assumptions about e_d (t) and e_s (t) made by us.
2. The long-run output is influenced by both the demand and supply shocks. However, because of the assumption of delayed price level response to demand shocks but not to the supply shocks, the rate of inflation is influenced by the current supply shock but is not influenced by the current demand shock. We can exploit this result to identify and separate the underlying unobserved demand and supply shocks by imposing the implied conditions on the short run matrix in the structural factorization estimated from the Structural Vector Auto Regression analysis.
3. The impulse response matrix involves four unknown parameters, namely, α, a, b and Γ(L). Like Γ(L), all of them can be thought of as unknown polynomials of the lag operator. It can be ascertained that the stationarity of Δ Y(t) and Δ P(t) claimed in the first observation above, remains valid even if α, a and b are considered to be polynomials as long as these polynomials extend up to finite number of lags or are convergent if they are infinite polynomials. Having obtained the impulse response matrix function in an explicit analytical form, it may be possible to solve for the four

parameters - (polynomials) by equating the terms in the matrix with corresponding polynomials estimated through a Vector Auto Regression exercise.

4. Using the demand and supply shocks, identified as noted in observation 2 made above, and the impulse – response function, estimated through a Vector Auto Regression exercise, the demand and supply components of output and the rate of inflation (of the price level of non-agricultural commodities) can be separately computed.
5. In particular, if the parameter (polynomial) a can be identified as noted above, the influence of productivity and other supply shocks such as the oil price hikes or fluctuations in agricultural production and prices on demand can be estimated. Adding these to the effects of demand shocks proper, on output and the rate of inflation, the total movement in these variables due to demand changes can be estimated. These variations in the rate of inflation can be used to characterize the cyclical component in the economic activity.
6. If the parameter (polynomial) α can be identified as noted in the third observation above, then observing that periods in which the component of inflation attributed to the total effect of demand as noted in observation (5) above is close to zero are periods when output as per our formulation was close to capacity output, estimates for capacity output may be obtained.

3. Structural VAR and Structural Factorization Exercise

We now turn to reporting the empirical part of the work. We use the data on logarithm of GDPNA (including forestry and mining) at constant (1999-00) prices (Y) and the logarithm of the corresponding deflator GDPNADEF (P) for the sample period from 1952-2008. Data for GDP originating in agriculture at constant and current prices for 2008-09 were available in National Accounts Statistics 2010 only for the base year 2004-05. Hence, these figures for the base year 1999-00 were obtained by splicing, in order to obtain the corresponding figures for GDPNA and GDPNADEF for 2008-09. We first note that applying the Phillips Perron test, the non-stationarity hypothesis is not rejected for either for Y or P but is rejected for both ΔY and ΔP at 1% and at 5% with only constant or with constant and trend. The results of applying the Augmented Dickey-Fuller test are similar. In any case, since the Phillips-Perron test is valid even with auto correlated disturbances while the Augmented Dickey-Fuller test is not, we accept the results of the Phillips-Perron test. Thus, we conclude that both ΔY and ΔP are stationary and hence Y and P are I(1) series.

The results of cointegration between Y and P (to be referred to as lngdpna and lngdpnadef in the statistical work, tables and charts) need to be first taken into account. First of all, all criteria for the selection of lag length to be used in the Vector Auto Regression for lngdpna and lngdpnadef , namely, Likelihood Ratio (LR) statistic, Final Prediction Error (FPE), Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC) and Hannan Quinn Information Criterion (HQIC) indicate an optimum lag length of two years. Accordingly, we use a lag length of two years in the VAR equation to test the cointegration between lngdpna and lngdpnadef. We find that Trace test and Max-eigenvalue test both indicate at 5 per cent level of significance that these two variables have one cointegrating vector when these variables are postulated to have no deterministic trends, but that they have no cointegrating vector when the variables are postulated to have linear deterministic trends. Since we have shown above that these two variables have deterministic linear trends as per our specification of the model if there is a constant term in the net investment function, as would be the case if some part of net investment is autonomous, we assume for the purposes of this paper that the two variables Y and P are not cointegrated. We can, therefore consider an unrestricted Vector Auto Regression (VAR) exercise for the two variables ΔY and ΔP (i.e., DLNGDPNA and DLNGDPNADEF, respectively), following the Blanchard-Quah approach. Dlngdpna and dlngdpnadef are co-integrated, and have one cointegrating vector if an intercept and a linear deterministic trend are assumed. We shall comment on this finding later on in the paper.

Vector Auto Regression (VAR) estimates for the system of two variables ΔY (DLNGDPNA) and ΔP (DLNGDPNADEF) for the sample period 1952-2008 are presented in Appendix Table 1. The lag length was selected at 1, based on the criteria for the selection of optimum lag length for the VAR for DLNGDPNA and DLNGDPNADEF. The estimated VAR equations presented in Appendix Table 1 can be written as:

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = a(0) + A(1)\begin{bmatrix} \Delta Y(t-1) \\ \Delta P(t-1) \end{bmatrix} + \begin{bmatrix} v_1 \\ v_2 \end{bmatrix} \qquad \ldots (19)$$

where, from the estimated equations, we have:

$$a(0) = \begin{bmatrix} 0.017870 \\ 0.030551 \end{bmatrix}$$

$$A(1) = \begin{bmatrix} 0.608781 & -0.017713 \\ 0.070599 & 0.519557 \end{bmatrix}$$

and $\begin{pmatrix} v1 \\ v2 \end{pmatrix}$ is the vector of VAR residuals.

From (19), we have the following equation, using the lag operator L

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = a(0) + A(1)L\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} + \begin{pmatrix} v1 \\ v2 \end{pmatrix}$$

Since ΔY (t) and ΔP (t) are stationary processes, we can write

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = \left[I - A(1)L\right]^{-1} a(0) + \left[I - A(1)L\right]^{-1}\begin{bmatrix} v1 \\ v2 \end{bmatrix} \qquad \ldots (20)$$

Ignoring the constant, the dynamic part of the two processes is given by:

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = \left[I - A(1)L\right]^{-1}\begin{bmatrix} v1 \\ v2 \end{bmatrix} \qquad \ldots (21)$$

The inverse of the polynomial matrix on the right-hand side will be a matrix of infinite polynomials. Hence, we have a moving average representation of the joint stochastic process of ΔY(t) and ΔP(t) in terms of the vector of VAR residuals or innovations v_1 and v_2 , given by:

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = v(t) + C(1)\ v(t-1) + \ldots\ldots. \qquad \ldots (22)$$

On the other hand, using Wold-decomposition, any stationary multivariate linear stochastic process can be represented as an infinite multivariate Moving Average Process of the underlying structural disturbances. Therefore, the joint stochastic process of ΔY(t) and ΔP(t) can be represented as given below:

$$\begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} = \Psi(0)\, e(t) + \Psi(1)\, e(t-1) + \Psi(2)\, e(t-2) + ... \quad \text{… (23)}$$

where ψ(0), ψ(1), … are 2x2 matrices of parameters, and e(t) are the vectors of the white noise disturbances with zero means and a constant variance-covariance matrix Σ. If the disturbance $e_d(t)$ and $e_s(t)$ are assumed to be not correlated with each other, their variance-covariance matrix Σ will be diagonal. Without any loss of generality, we can normalize the disturbances $e_d(t)$ and $e_s(t)$ so as to make their variances equal to unity and therefore the diagonal matrix Σ to be the identity matrix.

Through a structural factorization exercise, which we carry out with the help of the (E-views-5) computer software package, we seek to find 2x2 matrices A and B such that

$$A.v(t) = B\, e(t) \quad \text{… (24)}$$

showing the relation between the reduced form or VAR residuals v(t) and the structural innovations e(t).

We postulate

$$A = \begin{bmatrix} 1.0 & 1.0 \\ 0.0 & 1.0 \end{bmatrix} \quad \text{(24a)}$$

We can easily see from equation (24) and matrix A as postulated in equation (24a) that

$$\begin{bmatrix} v1 + v2 \\ v2 \end{bmatrix} = Be(t) \quad \text{(24b)}$$

Noting that the variables in the VAR are the dlngdpna (i.e. growth rate of non-agricultural output) and dlngdpnadef (the inflation rate in non-agricultural prices), this implies from equation (24) that we are postulating the *nominal* growth rate of non-agricultural output to be determined by both current demand and supply shocks whereas, in view of our assumption about the short-run stickiness of non-agricultural prices in response to demand ($b_{21} = 0$, as explained below), the *current* inflation rate in non-agricultural prices is determined only by the current supply shock.

From equation (24b), we have

$$\begin{bmatrix} v1 \\ v2 \end{bmatrix} = B(adj)e(t) \quad \text{(24c)}$$

where

$$B(adj) = A^{-1}B = \begin{bmatrix} b11 & (b12 - b22) \\ 0 & b22 \end{bmatrix} \quad \text{(24d)}$$

where bij are the elements of the matrix B.

Thus, B(adj) is simply the ψ(0) matrix in equation (23). In this case, clearly, the variance-covariance matrix Ώ of the VAR residuals will be given by:

$$\begin{aligned} Ώ &= E\,(A^{-1}B\ e(t) * (A^{-1}B(t)\ e(t)')\ ) \\ &= E\,(A^{-1}\ B\ \Sigma\ B'\ (A^{-1})') \\ &= E(A^{-1}BB'(A^{-1})') \end{aligned} \qquad \dots (25)$$

since the covariance matrix of the disturbances e(t), Σ, is restricted to be the identity matrix. In other words, matrix $A^{-1}B$ is simply the ψ(0) matrix when the structural disturbances $e_d(t)$ and $e_s(t)$ are normalized to make their variances equal to unity, as noted above. Also, correspondingly, the matrices ψ(j) get transformed to matrices $B(j) = C(j)\ A^{-1}B$, where the coefficient matrices C(j) are as defined in equation (22). Equation (25) imposes three restrictions on matrix B in view of the sample estimates of the variances of the VAR residuals from the two equations and the covariance between the two. Matrix B then can be uniquely determined if a fourth restriction is specified from outside. For example, in our exercise, the postulated delayed adjustment of the price level of non-agricultural commodities implies that

$$b_{21} = 0.$$

Imposing this restriction, which we now recognise as imposing the condition of the Choleski decomposition for our case, the matrix B in our case is estimated to be:

$$B = \begin{bmatrix} 0.016257 & -0.02228 \\ 0.000000 & -0.029723 \end{bmatrix} \qquad \dots (26)$$

It can be seen that matrix B is obtained as follows:

From equation (25), using the above-mentioned restriction on b_{21}, we have,

$Var.(v_1) = b_{11}(b11\text{-}b12) + (b12 - b_{22})^2$

$Var.(v_2) = (b_{22})^2$

$Cov.(v_1,v_2) = b_{22}\ (b_{12} - b_{22})$

From the above conditions, we obtain:

$b_{22} = +/- \sqrt{}\ (var.v_2)$

$b_{12} = [cov.(v_1,v_2) / (+/-)\sqrt{}\ (var.v_2)] + (-/+)\sqrt{}\ (var.v_2)$; and

$b_{11}=\sqrt{}[(var.v_2)\text{-}\{cov.(v_1,v_2)]^2/(var.v_2)\}]$ (26a)

We have chosen the negative sign for $\sqrt{}\ (var.v_2)$ so as to yield the economically meaningful sign pattern for the B matrix, as shown in eq.(26) for the responses of the two underlying variables to the demand and supply shocks. It may be noted that this choice does not affect the estimates of the demand shocks, but makes the signs of the supply shocks opposite of the VAR residuals in the equation for the rate of inflation. Thus, a positive supply shock reduces and a negative supply shock increases the rate of inflation, as one would expect.

The corresponding computer output for the Structural VAR estimates is shown as Appendix Table 2, the programme for which, however, chooses the positive sign for $\sqrt{}\ (var.v_2)$.

The adjusted B matrix computed from the above mentioned matrix B is given by:

$$B\ (adj) = \begin{bmatrix} 0.016257 & 0.007443 \\ 0.000000 & -0.029723 \end{bmatrix}$$

Accordingly, we have also re-worked the impulse responses to the demand and supply shocks.

The estimated demand and supply shocks $e_d(t)$ and $e_s(t)$ are then identified in view of equation (24c) as:

$$\begin{bmatrix} e_d(t) \\ e_s(t) \end{bmatrix} = \begin{bmatrix} \text{Demshock} \\ \text{Suppshock} \end{bmatrix} = [B\ (adj)]^{-1} v(t) \qquad \ldots (27)$$

Ignoring the constant and concentrating on the dynamic part of the two processes, the response of the system to the underlying structural disturbances (that is, the demand and supply shocks) can be given by:

$$\begin{aligned} \begin{bmatrix} \Delta Y(t) \\ \Delta P(t) \end{bmatrix} &= \left[I - A(1)L \right]^{-1} B(adj) \cdot e(t) \\ &= \left[I - A(1)L \right]^{-1} B(adj) \left([B(adj)]^{-1} v(t) \right) \end{aligned} \qquad \ldots (28)$$

since $([B(adj)]^{-1} v(t))$ gives the identified demand and supply shocks.

Indeed, the matrix given by

$$\left[I - A(1)L \right]^{-1} B(adj) \qquad \ldots (29)$$

gives the response of ΔY and ΔP to demand and supply shocks, respectively, and can be used to place restrictions on the long-run effects in response to the structural disturbances, an approach, for example, adopted by Blanchard and Quah, as stated earlier.

4. Estimation of the Demand and Supply Shocks

The demand and supply shocks identified and estimated by placing the restriction of the delayed response of Δ P(t) to the demand shocks, are shown along with the residuals from the VAR equations, in Chart I. Appendix Table 3 shows the corresponding data. The large negative innovation in the growth rate of output in 1957 is accounted for primarily by a large negative demand shock. The oil shock of 1973 is seen to be reflected in a moderate negative demand shock and a sizeable negative supply shock in that year. The large negative innovation in the growth rate of output in 1979 and the large positive innovation in inflation are seen to reflect the large negative demand and supply shocks appearing together in that year, the supply shocks possibly being the oil price shock and the bad agricultural harvest. Negative demand and supply shocks of 1987 appropriately reflect the bad agricultural harvest of that year. The large fiscal and revenue deficits (of Union and state governments) during the second half of the eighties are reflected in positive demand shocks during that period (except for 1987) which are especially high in 1988 and 1989. Large negative demand and supply shocks in 1990 and 1991 are also seen. The positive innovations in the growth rate of output in the years following the reforms introduced in 1992 and the following years are attributed to the positive demand shocks outweighing the negative supply shocks. The positive demand effects arising from the exchange rate depreciation and higher growth rates of exports came almost immediately during 1992-1995. The supply effects of restructuring came in later years. The year 1996 shows a strong negative demand shock following the build up of demand in the previous four years. The negative demand shocks of the recession of 2000-2001 are seen The high growth rates of GDPNA since 2002 appear to have been propelled by positive demand occurring since 2002 right through 2008 and positive supply shocks through most of this period, except in 2004 and 2008. The negative supply shock of 2004 raised the inflation rate in that year. The comparatively lower growth rate of GDPNA in 2008-09 marking the impact of the global recession on the Indian economy interestingly gets reflected as a negative supply shock in that year, probably reflecting the crunch in domestic credit supply and external borrowing affecting the production process in India's non-agricultural sector, rather than as a negative demand shock, which duly reflects that the annual growth rate exports at 17 per cent during that year had as yet not sagged. The residuals from the inflation equation appear to be almost perfectly the mirror images of the supply shocks identified through the restrictions on the short-run matrix, high inflation residuals from the vector auto-regression equation almost exactly coinciding with the identified negative supply shocks. This, of course, is merely a reflection of the short-run condition imposed to isolate the demand and supply shocks.

Cumulating the dynamic parts of output changes (that is, growth rates) attributable to demand shocks and adding to the constant part and then taking anti-logarithms yields the time path which would have been followed by output in the absence of supply shocks. That is,

$$\text{Dyn\_}\Delta Y_d(t) = LRY \times B\text{ (adj)} * \begin{bmatrix} \text{Demshock} \\ 0 \end{bmatrix} \qquad \dots (30)$$

and

$$Y_d(t) = Y(0) + LRY * a_0 + \sum_{k=1}^{t} \text{Dyn\_}\Delta Y_d(k) \qquad \dots (31)$$

where the LRY matrix is the inverse matrix giving responses of ΔY to VAR residuals, shown in equation (21), and Y(0) is the value of Y for the initial year, 1952, and $\text{Dyn\_}\Delta Y_d(k)$ is the dynamic part of $\Delta Y(k)$ obtained by setting supply shocks to zero. Since Y(t) is actually logarithm of GDPNA, we take anti-logarithms of $Y_d(t)$ to obtain the series showing the role played by demand in the long-run growth of GDPNA. Similarly, we can obtain the series showing the behaviour of GDPNA over time in response to the supply shocks alone. Blanchard and Quah (1989) assume that demand shocks have no influence on output in the long run. Therefore, the series showing the behavour of output in response to the supply shocks alone is interpreted there as giving the potential output. As we have argued above, in our context, as demand also influences output in the long run through its influence on capacity through investment, such interpretation is not available. Moreover, such a construction also has to be based on the assumption that the level of output in the initial year (1952 here) entirely represents the effect of either demand or supply side factors. Therefore, we do not present these series here. We suggest presently an alternative way of constructing the series showing capacity output, which takes the place of potential output in the context of our model.

We, therefore, concentrate first on the behaviour of the dynamic parts of GDPNA, i.e., the growth rates of output, and GDPNADEF, or the rate of inflation of GDPNA deflator, in response to the demand and supply shocks.

The dynamic part of the demand-induced inflation is given by:

$$Dyn\_\Delta P_d(t) = LRP \times B\ (adj) * \begin{bmatrix} Demshock \\ 0 \end{bmatrix}$$

where LRP matrix is the inverse matrix giving responses of ΔP to VAR residuals. It should be pointed out in the interest of clarity that the dynamic effects are computed here by cumulating the sum of the products of the demand (supply) shocks and the corresponding response effects (on output growth or inflation, as the case may be) over the past fifty years, assuming the demand (supply) shocks prior to 1952 to be zero.

The dynamic demand and supply components of GDPNA output growth are shown in Chart II a. The dynamic demand and supply components of GDPNA price inflation are shown in Chart II b. It is noteworthy that demand effects on GDPNA output growth are sizeable in India though supply side effects also play a significant role in governing it. GDPNA inflation in India appears to be almost entirely influenced by supply side shocks and demand effects on it are surprisingly extremely small.

5. Estimation of the Structural Parameters Treated as Polynomial Functions of the Lag Operator

In the above estimation, the effect on demand and output through the immediate response to supply shocks is not incorporated in computing the demand-induced variations in output. To show the total effect of demand on output, including the effect of current supply shocks through demand, we would need the estimate for a. (See equation (1) or (9) above).To show the capacity output series precisely for all years, in fact, we would need the estimate of α. In what follows, we show how these can be computed in principle.

With the restriction placed on the short-run matrix B, the estimated long-run responses of ΔY(t) and ΔP(t) to the structural disturbances or the pure demand and supply shocks are given by:

$$R = \left[I - A(1)L \right]^{-1} B(adj) \qquad \text{… (32)}$$

These impulse responses up to ten steps ahead have been shown in Table 4. For simplicity of computation, in what follows we use the impulse responses up to one step ahead, in view of the choice of VAR estimates with one lag on the basis of the Akaike Information Criterion, referred to earlier. Thus, we have truncated the response polynomial function in R above at two lags to yield the R matrix given below:

$$R = \begin{bmatrix} Dyn\_\Delta Y \\ Dyn\_\Delta P \end{bmatrix} = \begin{bmatrix} 1+0.608781L & 0.070599L \\ -0.017713L & 1+0.519557L \end{bmatrix} \times \begin{bmatrix} 0.016257 & 0.007443 \\ 0.000000 & -0.29723 \end{bmatrix}$$

$$= \begin{bmatrix} 0.016257 + 0.009896952717L & 0.007443 + 0.002432742906L \\ -0.000287960241L & -0.029723 - 0.01557463057L \end{bmatrix} \qquad \text{… (33)}$$

Equating the elements of this matrix with the corresponding elements of the matrix on the right side of equation (18), we can deduce the parameter (polynomials) a, b, α and Γ(L) as given below:

Comparing equations (18) and (33), we have the following equations:

$$[0.016257 + 0.009896952717L] = b[1 + \alpha\, bL\, (1 - \Gamma(L)]^{-1} \qquad \text{… (34)}$$

$[-0.000287960241L] = \alpha L(1-\Gamma(L))[0.016257 + 0.009896952717L]$ … (35)

$[-0.014837 - 0.002098414077L] = a[b]^{-1}[0.016257 + 0.009896952717L]$
$+ (1-\alpha L)[0.016257 + 0.09896952717L]$ … (36)

$0.007443 + 0.002432742906L = a[b]^{-1}\alpha L(1-\Gamma(L))[0.016257 + 0.009896952717L]$
$+ \alpha L(1-\Gamma(L))[1-\alpha L][0.016257 + 0.009896952717L] - (1-\alpha L)$ … (37)

Substituting for a $[b]^{-1}$ from equation (36) into equation (37), we can obtain the value of αL as a polynomial in L. Substituting this value of α L in equation (35), we get [1 - Γ (L)]. On substituting for [1 - Γ (L)] into equation (34), we get the value for b and then from equation (37) the value for a. Note that addition/subtraction and multiplication of polynomial functions of lag operators appearing as parameters are defined as addition/subtraction and multiplication of polynomial functions and that therefore these operations satisfy the distributive, associative and commutative laws. Further, observe that all the four polynomial functions of the lag operator appearing in the matrix on the right hand side of equation (33) are invertible, which must be a consequence of the stochastic processes ΔY and ΔP being stationary. Denoting the polynomials in the said matrix by A_{ij} (L), it can be easily checked that we can solve for the polynomials αL, b and a if $A_{11}(L)$ and [1- $A_{21}(L)$} are invertible, and for [1 - Γ (L)] if αL is invertible. In the present instance, it is easily seen that $A_{11}(L)$ and [1- $A_{21}(L)$] are invertible, and on solving for αL, it can be checked that it is also invertible.

The estimated polynomial coefficients, obtained by solving the above equations by using high school polynomial algebra (and using the inverses only of those polynomials which are invertible) are given below:

$\alpha L = 0.970277 - 0.015442793L - 3.71692E\text{-}05L^2 + 2.26279E\text{-}05L^3 - 1.37754E\text{-}05L^4$
$+ 8.38623E\text{-}06L^5 - 5.10538E\text{-}06L^6 + 3.10806E\text{-}06L^7 - 1.89213E\text{-}06L^8 + 1.15189E\text{-}06L^9$
$- 7.01249E\text{-}07L^{10} + 4.26907E\text{-}07L^{11} - 2.59893E\text{-}07L^{12} + 1.58218E\text{-}07L^{13} - 9.632E\text{-}08L^{14}$
$+ 5.86378E\text{-}08L^{15} + 4.13851E\text{-}08L^{16}$ … (38)

$b = 0.016257 + 0.009892271L - 2.84858E\text{-}06\,L^2$ … (39)

$a = 0.006959793 + 0.001887522L - 0.000153441L^2$ … (40)

$\Gamma(L) = 1.01826\,L - 0.0108\,L^2 + 0.0066\,L^3 - 0.0040\,L^4 + 0.0024\,L^5 - 0.0015\,L^6 + 0.0009\,L^7$
$- 0.0006\,L^8 + 0.0003\,L^9 - 0.0002\,L^{10} + 0.0001\,L^{11} - 0.0001\,L^{12} + 0.000046\,L^{13}$
$- 0.000028L^{14} + 0.000017L^{15}$ … (41)

Incidentally, it can be checked that the sum of the absolute values of coefficients of [-bαL(1-Γ)] = 0.000288115 < 1, so that the polynomial [1+bαL(1-Γ)] is indeed invertible. Further, it can also be checked that the sum of the absolute values of coefficients of αL = 0.985815 < 1, hence the polynomial αL is also invertible and therefore Γ (L) can be computed, as shown. (See Enders (2004, p. 30).

The demand components of the dynamic part of growth and inflation, respectively, are shown in Charts II a and II b. These charts show that while the demand components of the dynamic part of GDPNA growth are sizeable, often even more important than the corresponding supply component, quite surprisingly, the demand components of the dynamic parts of GDPNA inflation are negligibly small in comparison with the corresponding supply components. The latter almost fully account for GDPNA inflation. However, having estimated the coefficient a, we can also show the adjusted demand components of the dynamic part of growth and inflation by adding the demand effects of the current supply shocks. While doing so, we have also scaled the supply shocks by weighting them by the standard deviation of dlngdpna and dlngdpnadef, respectively, so that they are dimensionally comparable to dlngdpna and dlngdpnadef. These adjusted demand components of the dynamic parts of GDPNA growth and inflation are shown in Charts II c and II d, respectively. These charts show that the demand effect of the current supply shock considerably modifies the effect of demand on GDPNA growth and inflation. The demand components of the dynamic parts of GDPNA growth and inflation are now seen to be algebraically much larger. Charts II e and II f compare the demand and supply influences on GDPNA growth and inflation after making the adjustment for the demand effect of current supply shock. The adjusted demand components of GDPNA growth are quite large and often are quite dominant in comparison of the supply components. While supply components of GDPNA inflation still dominate, now the demand components are not negligible. The demand effects of the current supply shocks have been quite important in affecting GDPNA growth in the 1991 crisis and in the expansion during the post-1992 reform period. Also, while the supply shocks have kept the inflation rates low during 1999- 2003, the demand effects of these supply shocks appear to have exercised an inflationary influence during that period. The demand effects of the current supply shocks have substantially driven the post- 2003 GDPNA growth while the demand effects of current supply shocks have not been able to outweigh the anti-inflationary effect arising out of current favourable supply (productivity) shocks.

6. Growth Cycle Chronology Based on the Demand Component of the Dynamic Part of Inflation

The demand components of the dynamic part of inflation, shown in Chart II b, have an interesting interpretation in the context of the discussion of the trend and cycles. Since the demand induced changes in the rate of inflation can be attributed to the deviations of output from capacity output, they can be seen to directly depict the variations in the output gap. Therefore, they can be said to show the cycles.

The idea used here is that while the producers may transmit to consumers cost changes emanating from supply shocks irrespective of whether output is above or below capacity level, they respond by adjusting prices, albeit after a lag, when demand tends to push up output beyond capacity level. Therefore, the capacity output levels may themselves be marked off either by those for GDPNA one year prior to where the demand component of the dynamic part of inflation is close to zero or by those for GDPNA for the years just preceding the sign changes in it. While the two methods of selecting the years give somewhat different results, the former is chosen here for presentation. The output level in such years may be identified as the full capacity output and may also be considered as the trend level of output. Trend output for the intermediate years has been estimated by interpolation, using the annual growth rate of output for the period between any two successive years of full capacity output. The capacity output levels obtained in this manner are shown in Chart III a and the estimated deviation cycles, showing the percentage deviation of actual output from the estimated capacity output levels are shown in Chart III b.

The years with full capacity outputs are noted to be as given below:

1951, 1956, 1957, 1960, 1963, 1978, 1983, 1985, 1991, 1993, and 2001.

We may recall that growth cycles in an economy are characterized either as alternating phases of low or high growth rates of aggregate demand and output (step cycles) or as alternating phases of low or high aggregate demand and output relative to trend (deviation cycles). (See this author's (1982) paper and Victor Zarnowitz (1985, esp. pp, 532-533)). In our paper, "Growth Cycles in the Indian Economy", we identified five deviation cycles for the Indian economy during the period from 1950 to 1975, around the trend estimated by using the six year moving average analogous to the methodology developed by National Bureau of Economic Research (NBER). The five trough-peak-trough deviation cycles so developed were:

Table 1a. Growth Cycles in the Indian Economy Identified in Earlier Work (Based on Annual Data)

Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1953	1956	1958	1960	1962	1964
Trough	*Peak*	*Trough*	*Peak*	*Trough*	
1968	1969	1972	1973	1974	

The turning points for the deviation cycles for the Indian economy, identified through an analysis of monthly data for the the period from April 1951 to March 1983, in this author's paper (2001), using a Diffusion Index for 11 indicators defining the growth cycle, were found to be as given below:

Table 1b. Growth Cycles in the Indian Economy Identified in Earlier Work (Based on Monthly Data)

Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1953-11	1956-6	1958-6	1961-3	1962-2	1965-3
Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1968-1	1970-4	1970-11	1972-2	1975-1	1976-11
Trough	*Peak*	*Trough*			
1977-10	1978-5	1980-4			

The trough-to-trough growth cycles which may be identified in the present context, analogously to the phases of deficient (trough to peak) and excess capacity (peak to trough), are given below:

Table 2. Troughs and Peaks of the Growth Cycle

Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1953	1956	1958	1960	1962	1963
Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1967	1969	1974	1978	1980	1983
Trough	*Peak*	*Trough*	*Peak*	*Trough*	*Peak*
1984	1986	1987	1989	1992	1996
Trough					
2001					

Since we are using annual data, we troughs and peaks can be marked only approximately, and taking account of the postulated one year lag in the response of the price level of non-agricultural commodities to demand changes, the years 1956, etc., are to be understood as being *towards the beginning* of the financial year 1956 – 57, and so on.

This shows nine trough-to-trough growth cycles relative to the growth of capacity output during the 50-year period, 1953-2002. The above Table lists two minor slowdowns in the years in 1983-84 and 1986-87 as cyclical phases and has not shown the minor peak trough peak cycle of 1996-1998-1999, treating the period of 1996-2001 as a double dip growth recession.

It is now easier to note and interpret the periods and episodes of high and low growth rates of output, for example, the boom associated with the launching of the Second Five Year Plan, or the recession following the poor harvest of 1966 and the 1967 world recession, the expansion of the late eighties, ending with the 1991 crisis, followed by the expansion phase after the reforms of 1991. As the data extends only till 2008, the turning point of 2009 is as yet not seen. Indeed, no turning point could be identified after 2001.

7. Capacity Output and Growth Cycles Based on the Estimated Gamma Polynomial

While the estimates of capacity output in the above exercise are based on full capacity levels identified by the demand component of the dynamic part of inflation, the capacity output levels for intermittent years were interpolated by assuming constant growth rate of capacity during these periods.[5] They also did not make any use of the positive but delayed response of inflation to output gap or the negative response of demand to inflation, as given by the polynomials α and (-) b. In order to do this, we use the estimate of Γ(L) from equation (41), which is based on the complete model specified in the present paper. The growth rate of capacity output can then be estimated by using equation (13). Unfortunately, that would require an estimate of $\gamma_0 = \beta_0$, giving the constant term in the investment equation (5), showing the effect of autonomous factors on investment. In the absence of an estimate of γ_0 or β_0, we assume the same to be zero in the following exercise, recognising that this would possibly lead to an under-estimation of capacity growth and consequently an over-estimation of capacity utilisation. While using the estimated supply shocks (the standard deviation of which was set at unity by construction) in equation (13), we scale them down by the standard deviation of DLNGDPNA to make them correspond with the dimensionality of DLNGDPNA. Capacity growth rates for the years 1973, 1974 and 1980 turn out to be negative in this computation on account of the very large negative supply shocks in 1973 and 1974 and a negative growth rate of GDPNA in 1979 accompanied by a sizeable negative supply shock in 1980. While the possibility of negative growth rates of capacity output resulting from a very large decumulation of inventories cannot entirely be ruled out, we have replaced the negative growth rates of capacity output estimated

[5] Notice that given that the GDPNA generally curves upwards convexly to the year axis, this makes the cycle estimate for the corresponding period to be negative. The demand component of the dynamic part of inflation, therefore, appears to behave contra-cyclically and the correlation between the dynamic part of the demand component of inflation and the cycle estimate is (-) 0.88.

from the model for these years by zero. Finally, we consider 1991 as a year of Full capacity in order to arrive at estimates of GDPNACAP, the capacity output levels of GDPNA.

GDPNA and GDPNACAP computed in this manner using the estimated Gamma polynomial are shown in Chart III c, and the corresponding cycle estimates and capacity utilisation ratios given by (GDPNA/GDPNACAP)*100) are shown in Chart III d and Chart III e respectively. Low growth rates of estimated capacity output in 1953, 1966 and 1967 and in 1973 and 1974, relative to GDPNA growth, caused by the large negative supply shocks in those years, which greatly reduced the growth of capacity output in those years, show up 1953, 1967 and 1974 as peaks in GDPNA relative to capacity GDPNA in this estimation, which are the important respects in which the cycle estimates by this estimation differ from those yielded by the cycle estimates presented earlier. Otherwise, most of the cycles are similar to those shown earlier, particularly during the period from 1979 to 2001, except that they show much larger amplitudes. It may be noted that capacity utilisation shown here pertains to the entire non-agricultural sector and not merely that in the manufacturing or the industrial sector of India, which have been the subject of discussion in some other studies. Quite apart from the technical reason mentioned earlier for capacity utilisation reported here to be over-estimated, it should be pointed out that capacity utilisation is likely to be higher in non-agricultural sector as a whole compared to manufacturing sector, because it includes sectors such as electricity, water supply, education and health services, transport and communication, which are most likely to have had nearly full utilisation in India, reflecting continuing shortages in these sectors. Along with the cycles, capacity utilisation in non-agricultural sector in the country, as estimated here, shows a steady decline from the high levels in the early fifties to a relatively low point by the end of the eighties, first due to the expansion in public sector investment and then due to the stagnation of the mid- seventies. It then shows a sharp increase after 1980 till 1995, with a dip in 1991. While the transition of the economy from one of controls and repressed inflation to a de-regulated one under the New Economic Policy driven by aggregate demand would increase capacity utilisation, increasing capacity utilisation must have also been a consequence of the increasing share of the sectors other than manufacturing, on account of the reasons mentioned above. It is noteworthy that while the rapid increase in capacity utilisation after the reform in 1991 is clearly seen, the increase in capacity utilisation actually began much earlier in the early eighties. More interestingly, the cycle estimates as well as capacity utilisation, based on the estimated Gamma polynomial, show up an additional peak in GDPNA relative to capacity output in 2004, bringing out that while GDPNA growth was high in 2005, 2006, 2007 and 2008, it had begun to already slacken relative to capacity output and capacity utilisation had already begun to show a decline from 2005. Indeed, the cycle estimate foe 2008 is in fact negative and capacity utilisation for that year is less than full.

Chart III f compares the cycle estimates based on the demand component of the dynamic part of inflation with those based on the estimated Gamma polynomial. It may be noted apart from the aberrations in the years 1953, 1967 and 1974, which show up as peaks in the latter cycle estimates, for reasons explained above, other cycles indicated by the two methods are broadly similar. Choosing to treat 1974 as a Trough as indicated by cycle estimates based on the demand component of the dynamic part of inflation, and our earlier work, the following seven Peak-Trough -Peak cycles are common to the two methods.

Table 3. Cycles Relative to Capacity Output Indicated by the Two Methods

Peak	*Trough*	*Peak*	*Trough*
1956	1957/1958	1960	1962
Peak	*Trough*	*Peak*	*Trough*
1963	1967/1968	1969	1974
Peak	*Trough*	*Peak*	*Trough*
1978	1979/1980	1983	1984
Peak	*Trough*	*Peak*	*Trough*
1989	1991/1992	1995/1996	2001

The cycles shown in the present paper are similar to those identified in our earlier work on growth cycles, but have now been identified without imposing any arbitrary trend but are based on trend values giving capacity output levels characterised by the condition that when demand exceeds capacity level, it leads to a rise in the price level of non-agricultural sector after a lag of one year. The other commonly used methods of estimating trends such as the exponential trend or the Hodrick-Prescott trend (Hodrick and Prescott, 1997) are based on statistical assumptions used for obtaining a smooth trend. Thus, the exponential trend postulates the trend rate of growth to be constant whereas the Hodrick-Prescott trend minimises the sum of squares of deviations of actual values from the trend values subject to a loss function which imposes a penalty for loss of smoothness in the trend, that is, a penalty for the year to year changes in the trend values. Chart III g shows a comparison of the cycle estimates relative to capacity output based on the demand component of the dynamic part of inflation and the de-trending by using the H-P trends. It may be noted that while the cycles based on the demand component of the dynamic part of inflation are broadly similar to those indicated by H-P de-trending, they are not identical and the amplitude of cycles is much greater with Hodrick-Prescott de-trending. As regards the cycle estimates based on the estimated Gamma polynomial, they are different from those obtained by H-P de-trending precisely for the years (mentioned in the previous paragraph) for which they are different from those based on the demand component of the dynamic part of inflation.

8. Variance Decomposition of the Structural Factorization

The variance decomposition for the structural factorization under the short-run restriction imposed by us shows that the supply shocks explain variations in inflation almost entirely (that is about 99.5 per cent), while demand shocks explain variations in growth rate of output to the extent of 80 per cent. (See Appendix Table 6).

9. GDPNA Growth and Inflation

Estimating the dynamic parts of GDPNA growth and inflation also helps us in clearly understanding the relation between GDPNA Growth and inflation. Appendix Table 7 and Appendix Chart IV clearly show the negative relation between the *dynamic* parts of GDPNA growth (=dyn_dlnd1_update+ dyn_dlns1_update) and inflation (dyn_dlnd2_update+ dyn_dlns2_update) while the same is not so tight when the two are considered without isolating the dynamic parts. It is clear that the negative relationship between GDPNA growth and GDPNA inflation is clouded by the uncorrelated current random demand and supply shocks. The negative relation between the two is also an indication that the supply shocks have dominated the GDPNA growth and inflation in the Indian economy. Considering the co-integration between GDPNA growth and inflation, we find that when GDPNA growth is assumed to have no deterministic trend and the co-integrating equation no intercept term, the two have one co-integrating vector, which shows a positive relationship between GDPNA growth and inflation. However, we have argued earlier in this paper that these two variables would have linear deterministic trends if some part of net investment is autonomous. And when GDPNA growth and the co-integrating equation are accordingly postulated to have linear deterministic trends, the two have one co-integrating vector and it shows a negative long-run relationship between the two. These results are presented in Appendix Table 8. By looking at the dynamic parts of GDPNA growth and inflation, we can see the role played by the demand and supply shocks in leading to this negative relationship.

10. Concluding Remarks

In this paper, we have attempted to develop estimates of capacity output and cycles relative to capacity output in non-agricultural sector of the Indian economy during the period from 1951 to 2008, using an economic rather than a purely statistical or an engineering definition of capacity. We view that capacity output may be characterized by observing that price level of non-agricultural goods and services tends to increase when demand exceeds full capacity output level. Postulating a delayed response of the price level of non-agricultural goods and services after demand exceeds full capacity output enables us to estimate the underlying unobservable structural demand and supply shocks which may have impinged on the economy. We do this through a structural factorization based on vector auto regression model of the two key variables, namely, GDPNA growth rate and GDPNA inflation. In the process, we have also estimated the structural parameters of the model, which we have ventured to consider as unknown polynomial functions of the lag operator rather than as scalars, as usually considered. We use the estimated polynomial functions, in turn to estimate the demand effects of supply shocks, full capacity output and cycles relative to it as well as an index of capacity utilisation in India's non-agricultural sector during the period of this study. We identified nine cycles in GDP originating in India's non-agricultural sector relative to capacity output, based on the demand components of the dynamic part of inflation in non-agricultural sector. Capacity Output based on the estimated distributed lag function of past outputs and supply shocks shows that capacity utilisation in non-agricultural sector, while showing the above-mentioned cycles, has steadily declined up to 1979 and has increased after 1980. We have offered a few general comments on our findings to indicate their plausibility.

Before we conclude, one important caveat or limitation of our work needs to be re-stated. We assumed that the effect of the change in the relative price of agricultural commodities on demand for non-agricultural output, through changes in real money balances, is included with the effect of supply shocks on demand, treating the change in the relative price of agricultural commodities as a supply shock. Treating the effect of the change in this relative price through real balances purely as a demand effect, as being included in the demand shock $e_d(t)$, would make the two shocks correlated, making it difficult for us to interpret the demand and supply shocks estimated by us to be orthogonal (that is, pure and independent) shocks. To overcome this problem, one would probably need to expand the VAR system to include the variable ΔGDP Deflator (that is, the overall inflation rate) or ΔGDPA Deflator (that is, the rate of inflation in GDPA Deflator) as an additional exogenous variable. Till this is done, we may recognize that our estimates of demand shocks may have been somewhat under estimated and those in supply shocks somewhat overestimated. There is also scope for introducing monetary and fiscal policy responses to perceived demand and supply shocks. A greater elaboration of the open economy considerations may also yield better understanding of the cyclical influences on the Indian economy in recent years.

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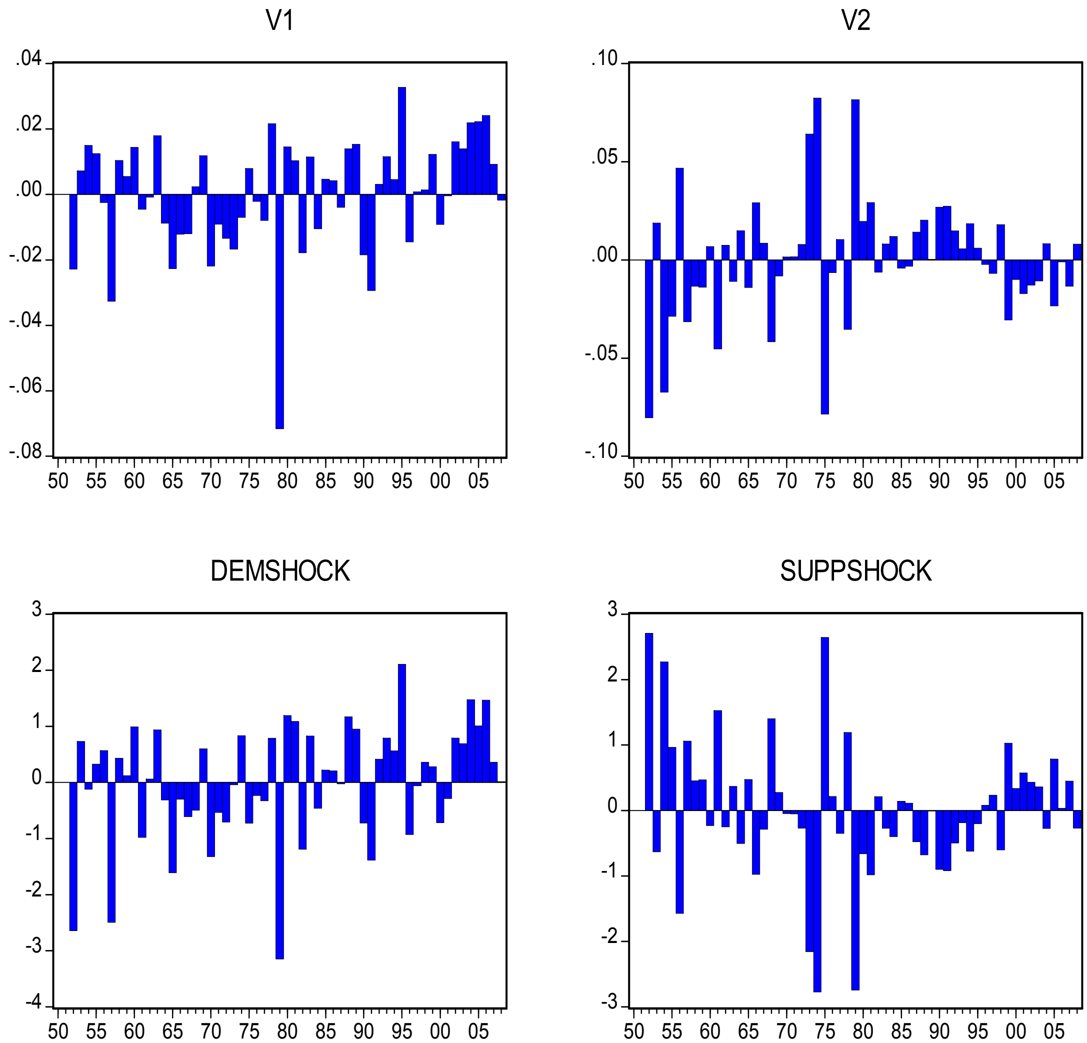
Charts:

Chart I: VAR Residuals and Demand and Supply Shocks



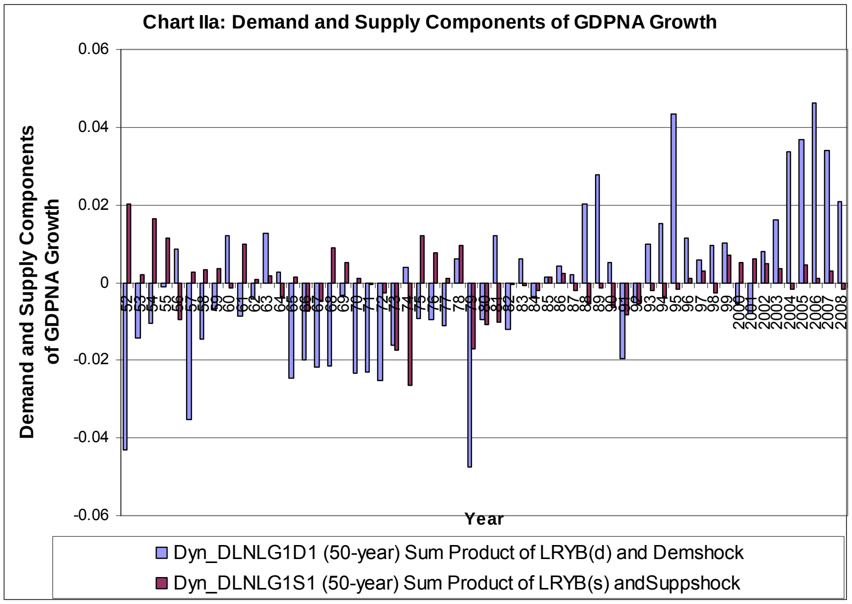


Chart IIa: Demand and Supply Components of GDPNA Growth
Demand and Supply Components of GDPNA Growth
Year
Dyn_DLNLG1D1 (50-year) Sum Product of LRYB(d) and Demshock
Dyn_DLNLG1S1 (50-year) Sum Product of LRYB(s) andSuppshock

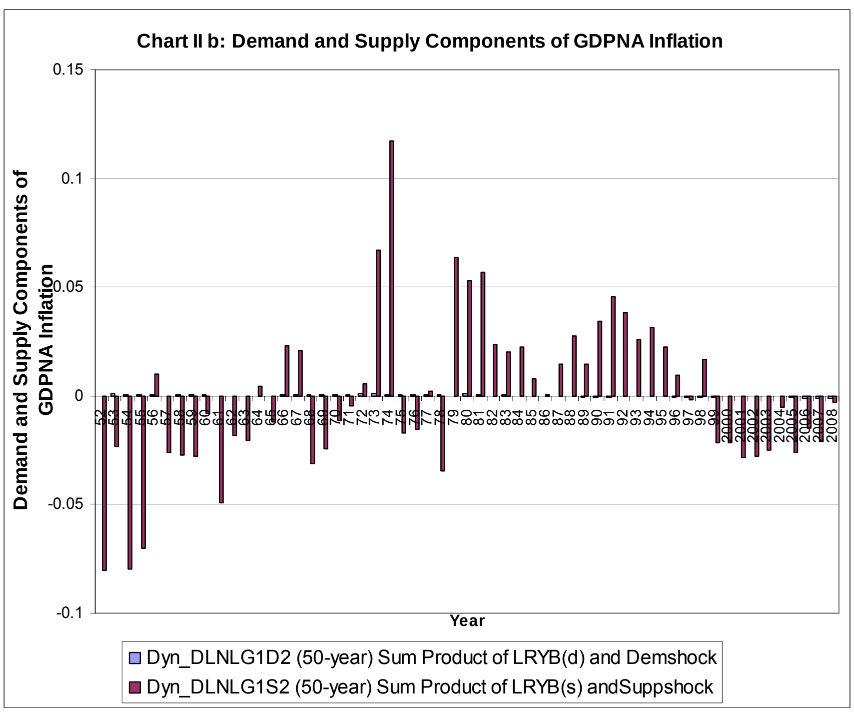


Chart II b: Demand and Supply Components of GDPNA Inflation
Demand and Supply Components of GDPNA Inflation
Year
Dyn_DLNLG1D2 (50-year) Sum Product of LRYB(d) and Demshock
Dyn_DLNLG1S2 (50-year) Sum Product of LRYB(s) andSuppshock

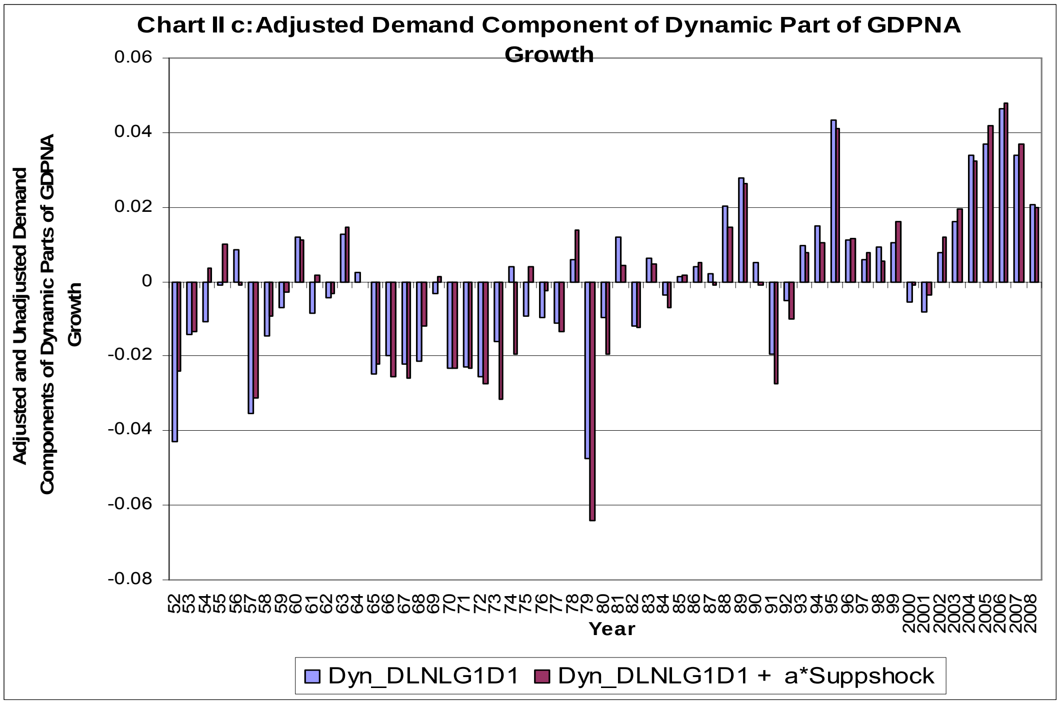


Chart II c:Adjusted Demand Component of Dynamic Part of GDPNA Growth
Adjusted and Unadjusted Demand Components of Dynamic Parts of GDPNA Growth
Year
Dyn_DLNLG1D1
Dyn_DLNLG1D1 + a*Suppshock

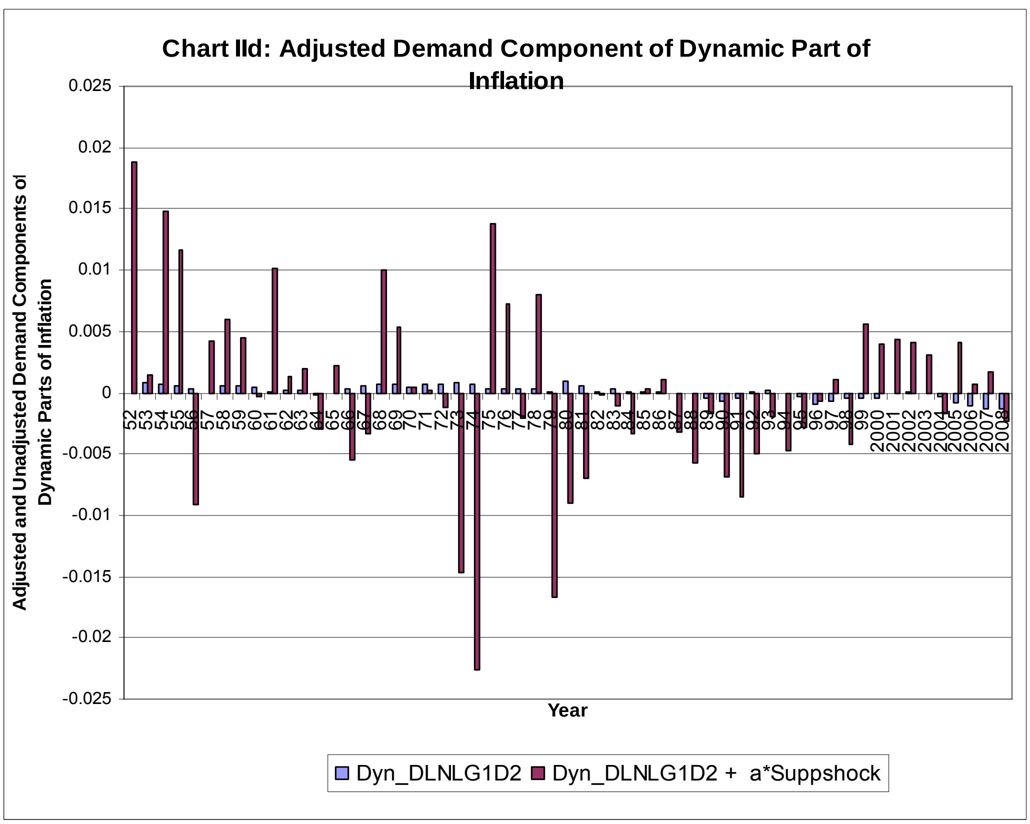


Chart IId: Adjusted Demand Component of Dynamic Part of Inflation
Adjusted and Unadjusted Demand Components of Dynamic Parts of Inflation
Year
Dyn_DLNLG1D2
Dyn_DLNLG1D2 + a*Suppshock

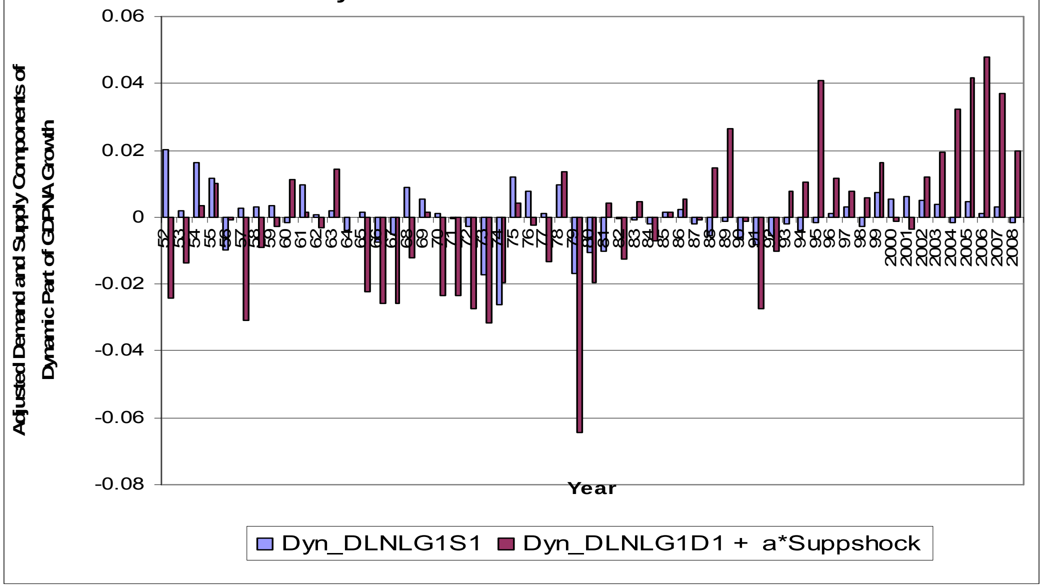


Chart II e: Adjusted Demand and Supply Components of Dynamic Part of GDPNA Growth

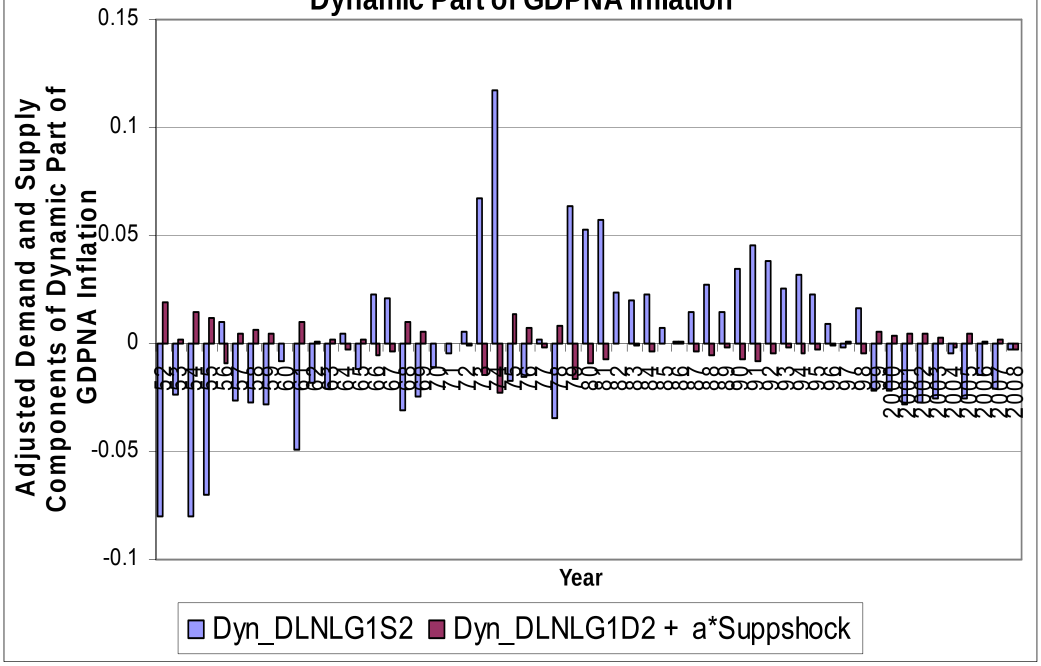


Chart II f: Adjusted Demand and Supply Components of Dynamic Part of GDPNA Inflation

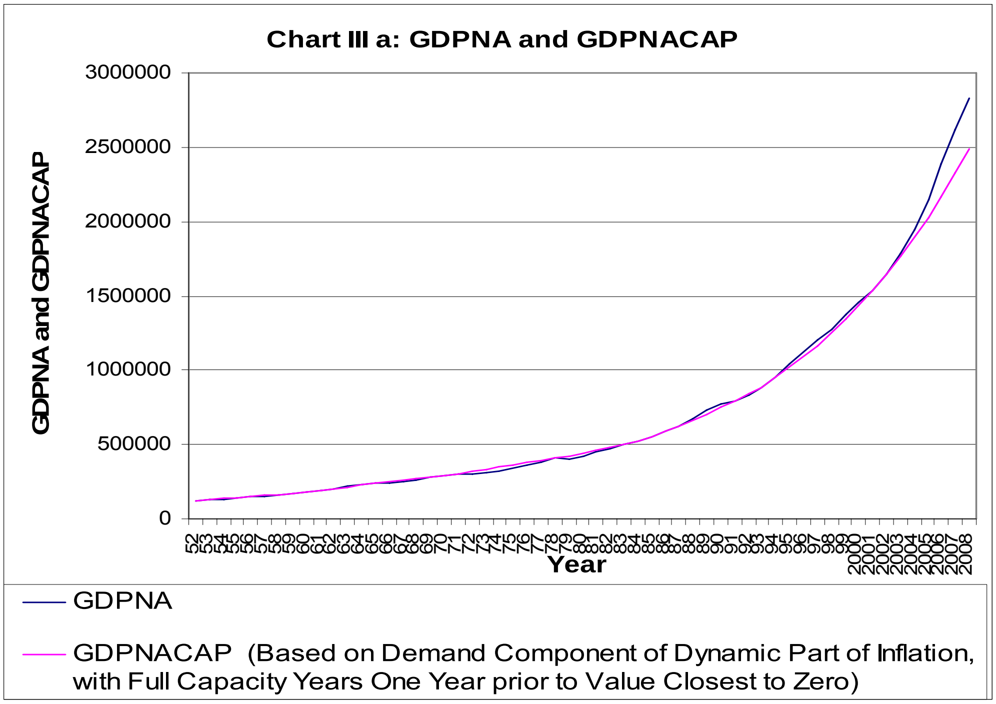


Chart III a: GDPNA and GDPNACAP
GDPNA and GDPNACAP
3000000
2500000
2000000
1500000
1000000
500000
0
Year
GDPNA
GDPNACAP (Based on Demand Component of Dynamic Part of Inflation, with Full Capacity Years One Year prior to Value Closest to Zero)

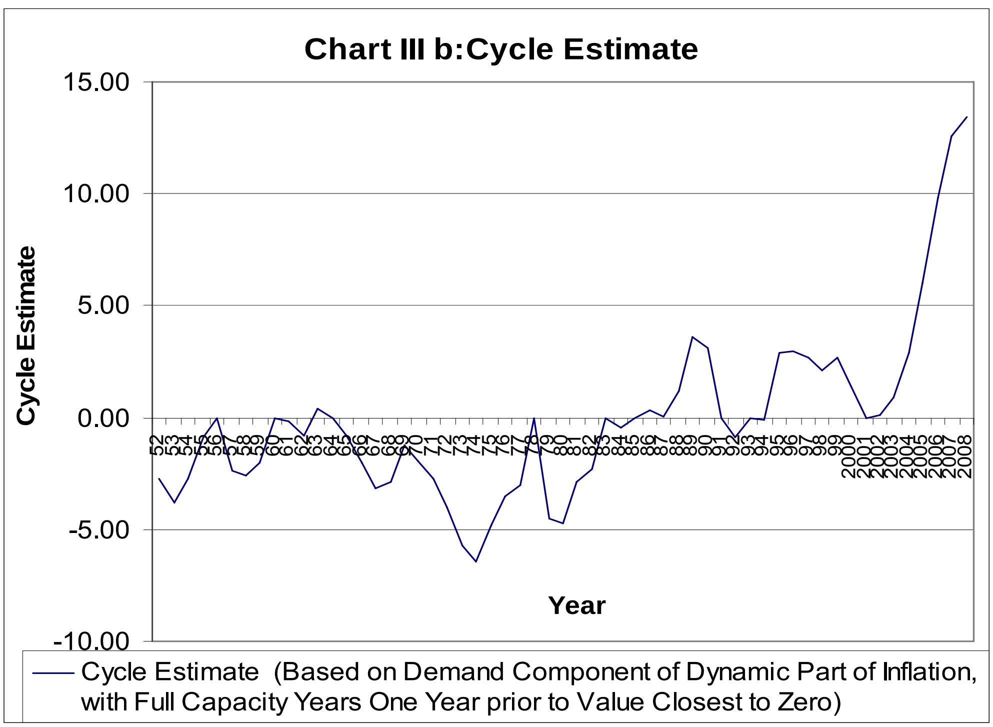


Chart III b:Cycle Estimate
Cycle Estimate
15.00
10.00
5.00
0.00
-5.00
-10.00
Year
Cycle Estimate (Based on Demand Component of Dynamic Part of Inflation, with Full Capacity Years One Year prior to Value Closest to Zero)

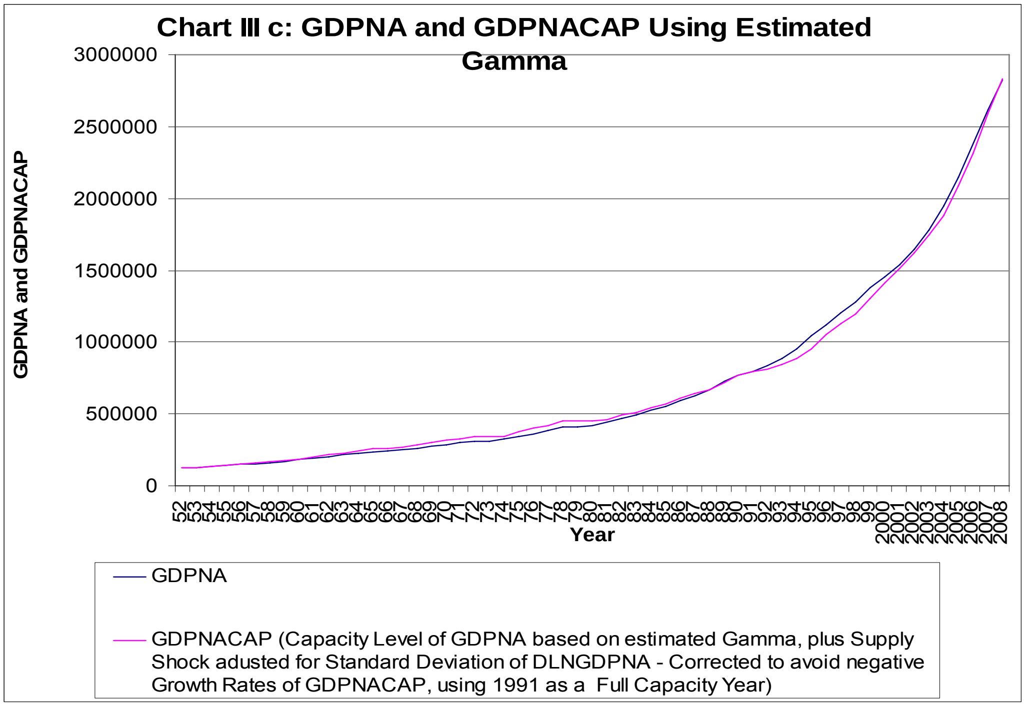


Chart III c: GDPNA and GDPNACAP Using Estimated Gamma
3000000
2500000
2000000
1500000
1000000
500000
0
GDPNA and GDPNACAP
Year
GDPNA
GDPNACAP (Capacity Level of GDPNA based on estimated Gamma, plus Supply Shock adusted for Standard Deviation of DLNGDPNA - Corrected to avoid negative Growth Rates of GDPNACAP, using 1991 as a Full Capacity Year)

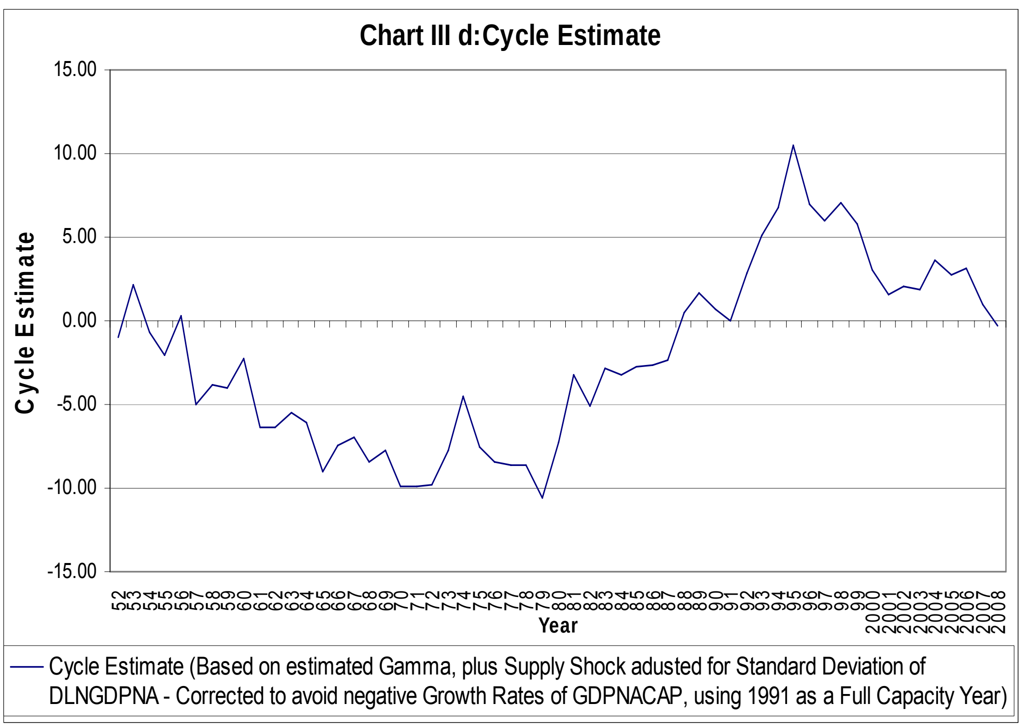


Chart III d:Cycle Estimate
15.00
10.00
5.00
0.00
-5.00
-10.00
-15.00
Cycle Estimate
Year
Cycle Estimate (Based on estimated Gamma, plus Supply Shock adusted for Standard Deviation of DLNGDPNA - Corrected to avoid negative Growth Rates of GDPNACAP, using 1991 as a Full Capacity Year)

Chart III e:Capacity Utilisation

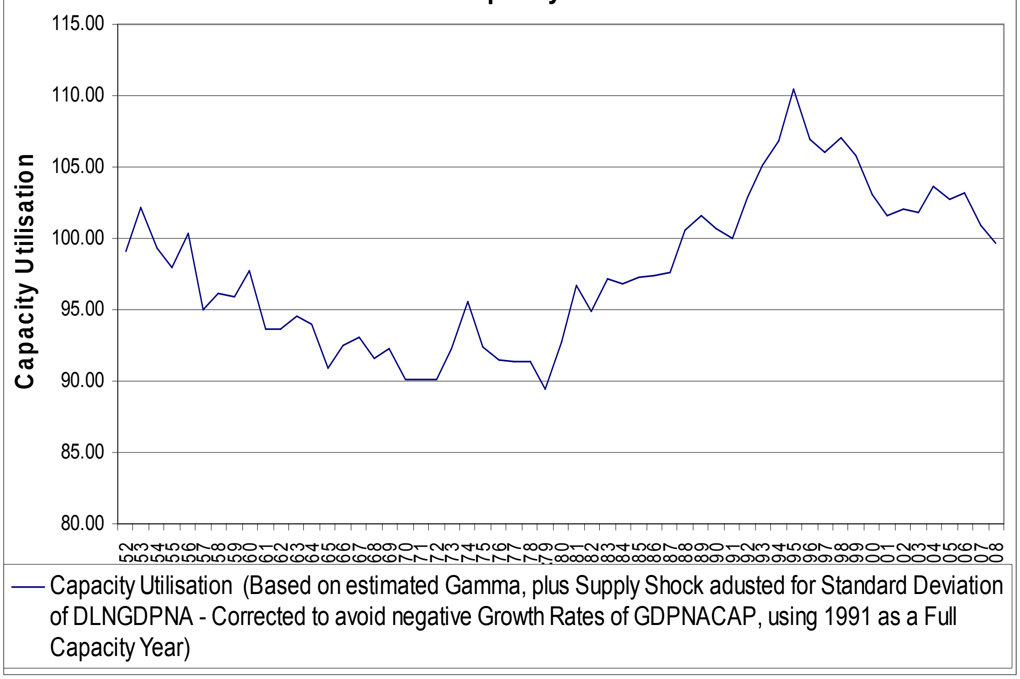
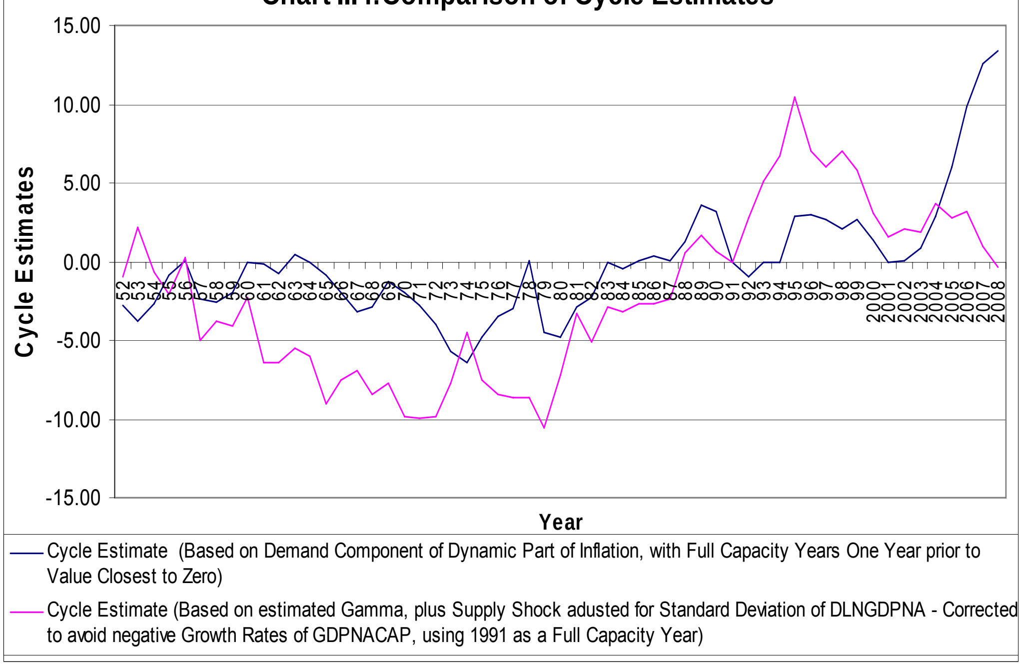


Chart III f:Comparison of Cycle Estimates



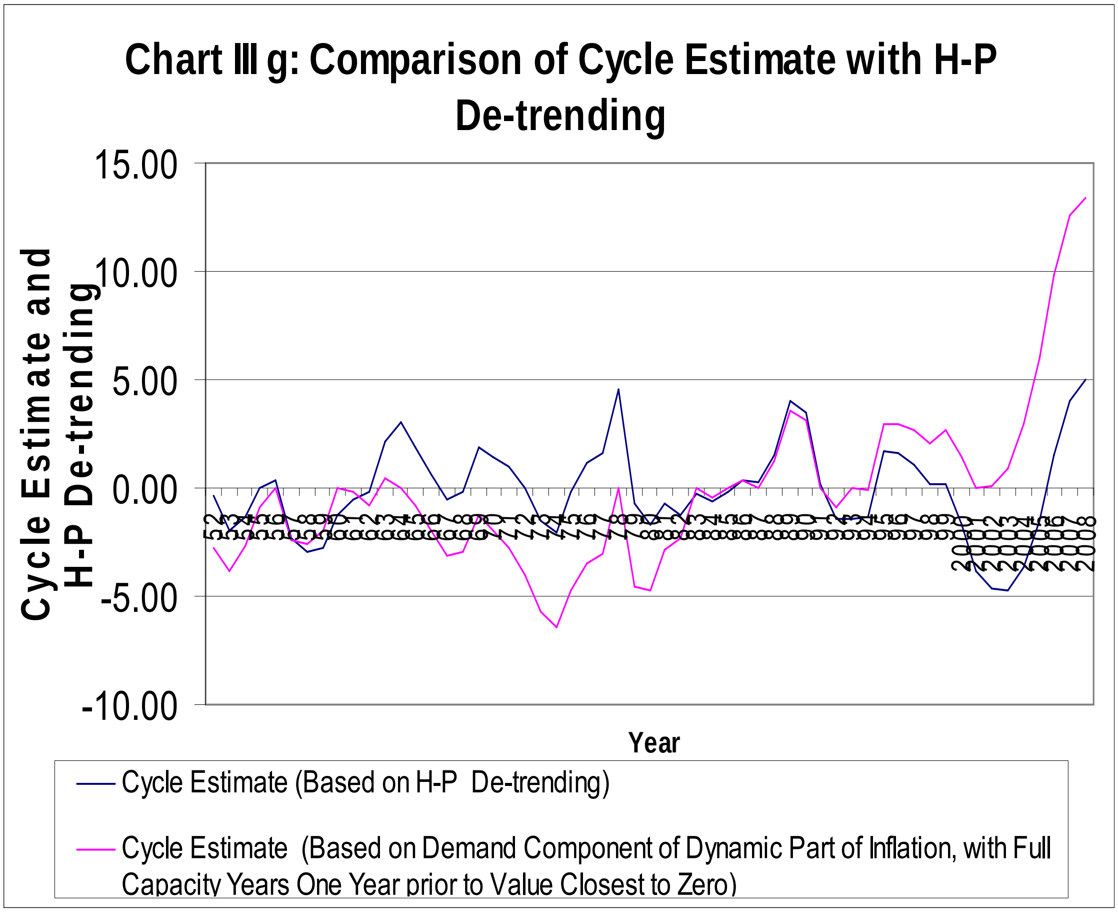


Chart III g: Comparison of Cycle Estimate with H-P De-trending
Cycle Estimate and H-P De-trending
15.00
10.00
5.00
0.00
-5.00
-10.00
Year
Cycle Estimate (Based on H-P De-trending)
Cycle Estimate (Based on Demand Component of Dynamic Part of Inflation, with Full Capacity Years One Year prior to Value Closest to Zero)

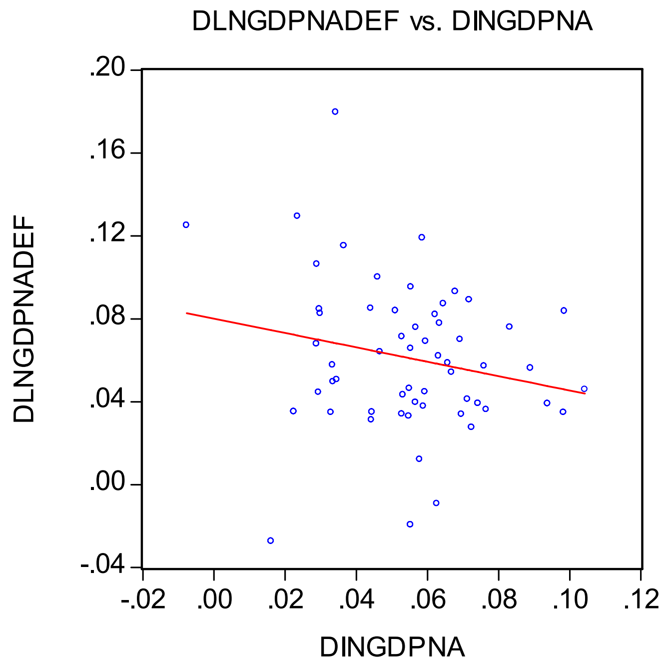


Chart IV a: Scatter of DLNGDPNADEF against DLNGDPNA

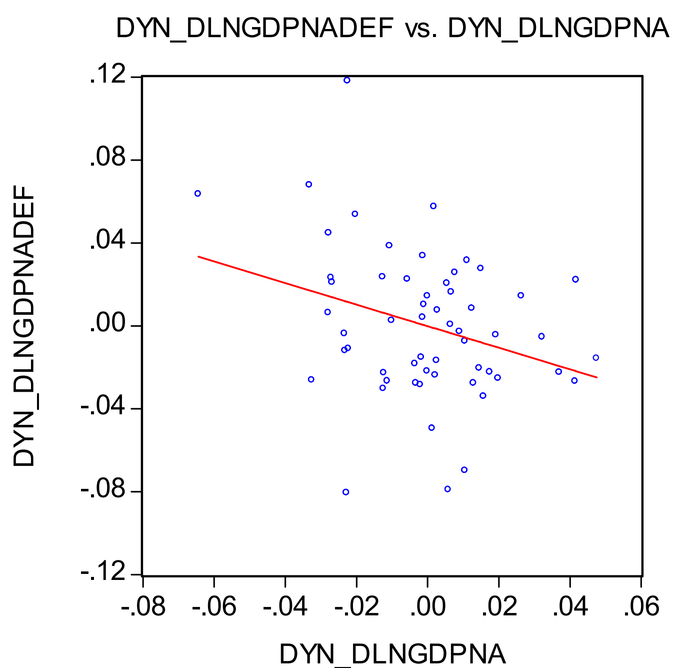


Chart IV b: Scatter of DYN_DLNGDPNADEF against YN_DLNGDPNA

Appendix Table 1. Vector Auto-regression Estimates

Sample (adjusted): 1952 2008
Included observations: 57 after adjustments
Standard errors in ( ) & t-statistics in [ ]

	DINGDPNA	DLNGDPNADEF
DINGDPNA(-1)	0.608781	-0.017713
	(0.11111)	(0.19764)
	[5.47913]	[-0.08962]
DLNGDPNADEF(-1)	0.070599	0.519557
	(0.06658)	(0.11843)
	[1.06038]	[4.38709]
C	0.017870	0.030551
	(0.00832)	(0.01480)
	[2.14790]	[2.06438]
R-squared	0.357365	0.273345
Adj. R-squared	0.333564	0.246432
Sum sq. resids	0.016874	0.053388
S.E. equation	0.017677	0.031443
F-statistic	15.01455	10.15657
Log likelihood	150.6842	117.8571
Akaike AIC	-5.181902	-4.030072
Schwarz SC	-5.074373	-3.922543
Mean dependent	0.055435	0.061334
S.D. dependent	0.021654	0.036221
Determinant resid covariance (dof adj.)		2.79E-07
Determinant resid covariance		2.51E-07
Log likelihood		271.4051
Akaike information criterion		-9.312458
Schwarz criterion		-9.097400

Appendix Table 2. Structural VAR Estimates

Sample (adjusted): 1953 2008
Included observations: 56 after adjustments
Estimation method: method of scoring (analytic derivatives)
Convergence achieved after 5 iterations
Structural VAR is just-identified

Model: Ae = Bu where E[uu']=I
Restriction Type: short-run pattern matrix

A =

1	1
0	1

B =

C(1)	C(2)
0	C(3)

	Coefficient	Std. Error	z-Statistic	Prob.
C(1)	0.016257	0.001536	10.58301	0.0000
C(2)	0.022280	0.003025	7.365023	0.0000
C(3)	0.029723	0.002809	10.58301	0.0000
Log likelihood	268.6444			

Estimated A matrix:

1.000000	1.000000
0.000000	1.000000

Estimated B matrix:

0.016257	0.022280
0.000000	0.029723

Appendix Table 3. VAR Residuals and Demand and Supply Shocks

	V_1	V_2	*Demand Shock*	*Supply Shock*
1952	-0.022795	-0.080448	-2.641333	2.706591
1953	0.007196	0.018725	0.731068	-0.629984
1954	0.014912	-0.067409	-0.121058	2.267907
1955	0.012483	-0.028692	0.325901	0.965313
1956	-0.002482	0.046757	0.567541	-1.573092
1957	-0.032649	-0.031495	-2.493432	1.059617
1958	0.010365	-0.013499	0.429642	0.454160
1959	0.005465	-0.013902	0.122026	0.467719
1960	0.014394	0.006845	0.990839	-0.230293
1961	-0.004533	-0.045359	-0.977514	1.526057
1962	-0.000846	0.007465	0.062947	-0.251152
1963	0.017961	-0.010927	0.936504	0.367628
1964	-0.008800	0.014923	-0.311441	-0.502069
1965	-0.022662	-0.014069	-1.610694	0.473337
1966	-0.012137	0.029038	-0.299288	-0.976954
1967	-0.012008	0.008481	-0.608000	-0.285335
1968	0.002384	-0.041683	-0.495413	1.402382
1969	0.011835	-0.008185	0.601918	0.275376
1970	-0.021853	0.001447	-1.321932	-0.048683
1971	-0.009075	0.001560	-0.534192	-0.052485
1972	-0.013427	0.007931	-0.703757	-0.266830
1973	-0.016712	0.064096	-0.040695	-2.156445
1974	-0.007060	0.082347	0.834145	-2.770481
1975	0.007879	-0.078543	-0.725172	2.642499
1976	-0.002155	-0.006417	-0.231402	0.215893
1977	-0.007939	0.010411	-0.327979	-0.350267
1978	0.021643	-0.035418	0.785748	1.191602
1979	-0.071608	0.081548	-3.148637	-2.743599
1980	0.014498	0.019574	1.193305	-0.658547
1981	0.010332	0.029205	1.085396	-0.982572
1982	-0.017812	-0.006269	-1.192215	0.210914
1983	0.011477	0.008127	0.831156	-0.273425
1984	-0.010496	0.011885	-0.462561	-0.399859
1985	0.004635	-0.004153	0.221138	0.139723
1986	0.004192	-0.003297	0.207073	0.110924
1987	-0.003947	0.014166	-0.024584	-0.476601
1988	0.013967	0.020169	1.169808	-0.678565
1989	0.015332	0.000298	0.947692	-0.010026
1990	-0.018458	0.026830	-0.722116	-0.902668
1991	-0.029355	0.027274	-1.385573	-0.917606
1992	0.003056	0.014780	0.415642	-0.497258

1993	0.011494	0.005578	0.792938	-0.187666
1994	0.004569	0.018390	0.564316	-0.618713
1995	0.032743	0.005999	2.106491	-0.201830
1996	-0.014523	-0.002336	-0.929320	0.078592
1997	0.000773	-0.006924	-0.059104	0.232951
1998	0.001392	0.017931	0.361822	-0.603270
1999	0.012237	-0.030611	0.281210	1.029876
2000	-0.009167	-0.009970	-0.717451	0.335430
2001	-0.000409	-0.017081	-0.288263	0.574673
2002	0.016068	-0.012799	0.791227	0.430609
2003	0.013932	-0.010728	0.691738	0.360933
2004	0.021907	0.008219	1.474143	-0.276520
2005	0.022246	-0.023371	1.008404	0.786293
2006	0.024099	-0.001000	1.466973	0.033644
2007	0.009187	-0.013391	0.358844	0.450527
2008	-0.001743	0.007976	0.015642	-0.268344

Appendix Table 4. Demand and Supply Components of GDPNA Growth and GDPNA Inflation

Year	***Demand GDPNA Growth*** *DYN_DLNLG1D1*	***Component of GDPNA Inflation*** *DYN_DLNLG1D2*	***Supply GDPNA Growth*** *DYN_DLNLG1S1*	***Component of GDPNA Inflation*** *DYN_DLNLG1S2*
1952	-0.04294	0	0.020145	-0.08044
1953	-0.01426	0.000761	0.001896	-0.023427
1954	-0.01059	0.000648	0.01638	-0.079607
1955	-0.00111	0.000524	0.011537	-0.07034
1956	0.008591	0.000292	-0.009651	0.010002
1957	-0.03529	-5.02E-07	0.002717	-0.026124
1958	-0.0145	0.000625	0.003190	-0.027119
1959	-0.0068	0.000581	0.003509	-0.028047
1960	0.012011	0.000422	-0.001558	-0.007790
1961	-0.00855	6.74E-06	0.009860	-0.049374
1962	-0.00418	0.000155	0.000647	-0.018363
1963	0.01269	0.000155	0.001834	-0.020478
1964	0.002673	-0.00014	-0.004066	0.004250
1965	-0.02457	-0.00012	0.001348	-0.011788
1966	-0.01983	0.000372	-0.007283	0.022887
1967	-0.02193	0.000544	-0.004942	0.020500
1968	-0.02137	0.000671	0.008877	-0.030940
1969	-0.00318	0.000727	0.005269	-0.024417
1970	-0.02337	0.000434	0.001122	-0.011332

1971	-0.02288	0.000639	-0.000508	-0.004348
1972	-0.02533	0.000738	-0.002602	0.005680
1973	-0.01603	0.000832	-0.017233	0.067087
1974	0.003862	0.000716	-0.026376	0.117499
1975	-0.00939	0.000304	0.011906	-0.017020
1976	-0.00946	0.000324	0.007654	-0.015470
1977	-0.01107	0.000336	0.000960	0.002237
1978	0.006061	0.00037	0.009611	-0.034269
1979	-0.04747	8.51E-05	-0.016989	0.063565
1980	-0.00949	0.000885	-0.010756	0.052898
1981	0.011928	0.000628	-0.010127	0.056876
1982	-0.01208	0.000115	-0.000580	0.023461
1983	0.006169	0.000274	-0.000732	0.020326
1984	-0.00375	3.29E-05	-0.001987	0.022457
1985	0.001317	8.34E-05	0.001416	0.007551
1986	0.004174	2.00E-05	0.002221	0.000601
1987	0.002143	-6.35E-05	-0.002153	0.014438
1988	0.020318	-7.10E-05	-0.005342	0.027706
1989	0.027771	-0.0004	-0.001371	0.014787
1990	0.005139	-0.0007	-0.006509	0.034535
1991	-0.01945	-0.00045	-0.008354	0.045329
1992	-0.00511	0.000109	-0.005587	0.038478
1993	0.009786	0.000147	-0.002081	0.025668
1994	0.015142	-9.69E-05	-0.004060	0.031761
1995	0.043456	-0.00032	-0.001732	0.022572
1996	0.011325	-0.00094	0.001124	0.009422
1997	0.005868	-0.00069	0.003084	-0.002048
1998	0.009406	-0.00046	-0.002758	0.016811
1999	0.010265	-0.00041	0.007173	-0.021825
2000	-0.00544	-0.00039	0.005323	-0.021435
2001	-0.00803	-0.00011	0.006004	-0.028310
2002	0.007968	8.63E-05	0.004862	-0.027613
2003	0.016103	-9.63E-05	0.003697	-0.025160
2004	0.033761	-0.00034	-0.001584	-0.004919
2005	0.036923	-0.00077	0.004541	-0.025896
2006	0.046272	-0.00106	0.001187	-0.014535
2007	0.033929	-0.00137	0.003049	-0.020962
2008	0.020813	-0.00131	-0.001621	-0.002970

Appendix Table 5. Impulse Responses to One Unit change

Uncumulated

Response of DINGDPNA:

Period	DINGDPNA	DLNGDPNADEF
1	1	0
2	0.608781	0.070599
3	0.369364	0.07966
4	0.223451	0.067465
5	0.134838	0.050827
6	0.081186	0.035927
7	0.048788	0.024398
8	0.029269	0.016121
9	0.017533	0.010442
10	0.010489	0.006663

Response of DLNGDPNADEF:

Period	DINGDPNA	DLNGDPNADEF
1	0	1
2	-0.017713	0.519557
3	-0.019986	0.268689
4	-0.016926	0.138188
5	-0.012752	0.070602
6	-0.009014	0.035781
7	-0.006121	0.017954
8	-0.004045	0.008896
9	-0.00262	0.004336
10	-0.001672	0.002068

Nonfactorized One Unit

Accumulated

Accumulated Response of DINGDPNA:

Period	DINGDPNA	DLNGDPNADEF
1	1	0
2	1.608781	0.070599
3	1.978145	0.150259
4	2.201596	0.217724
5	2.336434	0.268551
6	2.41762	0.304478
7	2.466408	0.328876
8	2.495678	0.344997
9	2.513211	0.355439
10	2.523699	0.362102

Accumulated Response of DLNGDPNADEF:

Period	DINGDPNA	DLNGDPNADEF
1	0	1
2	-0.01771	1.519557
3	-0.0377	1.788246
4	-0.05463	1.926435
5	-0.06738	1.997037
6	-0.07639	2.032818
7	-0.08251	2.050772
8	-0.08656	2.059668
9	-0.08918	2.064005
10	-0.09085	2.066073

Nonfactorized One Unit

Appendix Table 6. Variance De-composition

Variance Decomposition of DINGDPNA:				*Variance Decomposition of DLNGDPNADEF:*			
Period	*S.E.*	*DINGDPNA*	*DLNGDPNADEF*	*Period*	*S.E.*	*DINGDPNA*	*DLNGDPNADEF*
1	0.017677	100.0000	0.000000	1	0.031443	9.560009	90.43999
		(0.00000)	(0.00000)			(6.64232)	(6.64232)
2	0.020456	98.93493	1.065072	2	0.035480	9.794308	90.20569
		(3.29941)	(3.29941)			(7.20811)	(7.20811)
3	0.021383	97.78434	2.215662	3	0.036499	9.915188	90.08481
		(6.00893)	(6.00893)			(7.99082)	(7.99082)
4	0.021729	96.99240	3.007596	4	0.036769	9.969764	90.03024
		(7.63390)	(7.63390)			(8.45969)	(8.45969)
5	0.021864	96.54617	3.453826	5	0.036841	9.992175	90.00783
		(8.54439)	(8.54439)			(8.68214)	(8.68214)
6	0.021917	96.32269	3.677312	6	0.036860	10.00080	89.99920
		(9.04209)	(9.04209)			(8.77342)	(8.77342)
7	0.021938	96.21915	3.780848	7	0.036865	10.00397	89.99603
		(9.31473)	(9.31473)			(8.80625)	(8.80625)
8	0.021947	96.17375	3.826246	8	0.036866	10.00510	89.99490
		(9.46958)	(9.46958)			(8.81754)	(8.81754)
9	0.021950	96.15464	3.845362	9	0.036866	10.00550	89.99450
		(9.56360)	(9.56360)			(8.82296)	(8.82296)
10	0.021951	96.14683	3.853167	10	0.036866	10.00563	89.99437
		(9.62523)	(9.62523)			(8.82753)	(8.82753)

Note: Cholesky Ordering: DLNGDPNA DLNGDPNADEF Standard Errors: Monte Carlo (100 repetitions)

Appendix Table 7. Regression of DLNGDPNA on DLNGDPNADEF

Dependent Variable: DINGDPNA

Method: Least Squares

Sample (adjusted): 1951 2008

Included observations: 58 after adjustments

Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
DLNGDPNADEF	-0.126768	0.078944	-1.605794	0.1139
C	0.062724	0.005581	11.23881	0.0000
R-squared	0.044019	Mean dependent var		0.054986
Adjusted R-squared	0.026948	S.D. dependent var		0.021734
S.E. of regression	0.021439	Akaike info criterion		-4.813340
Sum squared resid	0.025739	Schwarz criterion		-4.742290
Log likelihood	141.5869	F-statistic		2.578573
Durbin-Watson stat	0.761338	Prob(F-statistic)		0.113944

Appendix Table 8. Regression of DYN_DLNGDPNA on DYN_DLNGDPNADEF

Dependent Variable: DYN_DLNGDPNA

Method: Least Squares

Sample (adjusted): 1952 2008

Included observations: 57 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
DYN_DLNGDPNADEF	-0.180304	0.075555	-2.386382	0.0205
C	-0.000470	0.002675	-0.175734	0.8611
R-squared	0.093827	Mean dependent var		-0.000490
Adjusted R-squared	0.077351	S.D. dependent var		0.021022
S.E. of regression	0.020192	Akaike info criterion		-4.932573
Sum squared resid	0.022425	Schwarz criterion		-4.860887
Log likelihood	142.5783	F-statistic		5.694820
Durbin-Watson stat	0.810544	Prob(F-statistic)		0.020483

Appendix Table 9. Co-integration of DLNGDPNA and DLNGDPNADEF

Sample (adjusted): 1953 2008

Included observations: 56 after adjustments

Trend assumption: Linear deterministic trend (restricted)

Series: DINGDPNA DLNGDPNADEF

Lags interval (in first differences): 1 to 1

Unrestricted Co-integration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.362482	36.31956	25.87211	0.0018
At most 1	0.179950	11.10986	12.51798	0.0850

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.362482	25.20970	19.38704	0.0063
At most 1	0.179950	11.10986	12.51798	0.0850

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level

* denotes rejection of the hypothesis at the 0.05 level

**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

DINGDPNA	DLNGDPNADEF	@TREND(51)
78.50372	25.53568	-0.064361
-16.14693	28.15306	0.005794

Unrestricted Adjustment Coefficients (alpha):

D(DINGDPNA)	-0.008589	0.005256
D(DLNGDPNADEF)	-0.005682	-0.012734

1 Cointegrating Equation(s): Log likelihood 274.4901

Normalized cointegrating coefficients (standard error in parentheses)

DINGDPNA	DLNGDPNADEF	@TREND(51)
1.000000	0.325280	-0.000820
	(0.07847)	(0.00015)

Adjustment coefficients (standard error in parentheses)

D(DINGDPNA)	-0.674296
	(0.18324)
D(DLNGDPNADEF)	-0.446022
	(0.33692)

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