Examining Sustainability of Federal Finances in India: An Application of Non-stationary Panel Methods

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Abstract:

This paper examines the fiscal sustainability of Indian States during the 1990s on the basis of their budgetary data. Sustainability has been discussed using the inter-temporal budget constraint framework and has been tested by applying the panel co-integration technique. The panel analysis reveals that revenue receipts and revenue expenditures are co-integrated across the States. Further, the insensitivity of the results to the choice of the period of analysis attests the robustness of the result that the state finances in India may not be unsustainable.

1. Introduction:

The deterioration in fiscal performance of the Indian States was clearly discernible since the mid-1980s and was reflected in major fiscal indicators such as fiscal/revenue deficits and debt-GDP ratio. There has been a level jump in the revenue deficit of the States in the second half of the 1990s and especially after 1997-98. The combined revenue deficit of all sates jumped from 1.07 percent in 1997-98 to 2.51 in 1998-99. Over the last few years, the steady deterioration in the state governments' deficit has been a major issue of concern. The state deficit is estimated at 4.7% of GDP in 2003-04. The state's share in the combined deficit is estimated at 46% of GDP in 2003-04 up from 40%in 1995-96. While the state government's revenue collections did not change, its aggregate expenditure rose to 16.5% of GDP from 14.3% in this period. This increase in expenditure has been largely due to higher non-development expenditure on items such as interest, pension and

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administrative services to 6.5% of GDP in 2002-03 compared with 4.7% in 1995-96 and 4.0% in 1990-91. State governments' revenue deficit has risen to 2.5% of GDP (53% of fiscal deficit) in 2002-03 compared with 0.7% in 1995-96 (26% of its fiscal deficit). An array of factors responsible for the disparity in the growth of receipts and expenditure and the consequent widening of the fiscal deficit have been identified. In a recent IMF Working Paper "The Decentralisation Dilemma of India", India is ranked among the most decentralised economies in the world, with the States undertaking more than half of general government spending. But since they account for less than 40 per cent receipts, there has been a precipitous and unchecked deterioration in the State finances. A survey on worsening State finances as set out in RBI (2003) reveals that, amongst others, reluctance to raise additional resources (Kurian, 1999), competitive reduction in taxes, absence of service tax and agricultural income tax (Rao, 2002), sluggishness in Central Transfer reflecting the precariousness of Centre's own finances (Chakraborty, 1999), inappropriate user charges (Mohan, 2000), impact of pay revisions (Acharya, 2002) and increase in non-developmental expenditure, particularly the revenue component of the non-developmental expenditure, and interest payments as a proportion of revenue receipts (Indira Rajaraman, 1999) were responsible[1].The impacts of various factors identified are likely to vary across the States, which also witness large disparities across them in terms of level of income and the tax and expenditure policies.

It is thus clear that the state finances are not comfortable. But could we say that they are unsustainable? This is essentially an inter-temporal issue, which needs to be addressed empirically. Fiscal sustainability implies that the fiscal policy currently in operation can be continued unaltered without jeopardizing the objectives of economic policy. The former would typically be conditional on the behavior of debt-GDP ratio which is analyzed through different approaches. One of them is the 'accounting approach' wherein the sustainability aspect is judged through the application of the Domar stability condition that

[1] Some other factors include: the low and declining buoyancies in tax and non-tax receipts, constraints on internal resources mobilization due to losses incurred by State Public Sector Undertakings and decelerating resources transfer from Centre. Structural imbalances in the form of large revenue deficits, rising interest burden, increasing distortions in the pattern of expenditure, and very slow growing non-tax revenues are major problem areas for State finances.

the growth rate of GDP must exceed the interest rate on public debt. If not so, rising debt servicing obligations would lead to higher fresh borrowings at a rate higher than GDP growth, making the fiscal policy unsustainable. On an assessment, we find that the Domar stability condition has been violated for all[2] succeeding years beginning with 1999-00. One possible reason for this could be that a sizeable proportion of the domestic debt had been contracted at administered interest rates at higher level. In recent years, however, the rates on market related borrowings have come down and are lower than the nominal GDP growth rate. These developments confirm to weak sustainability condition.

Another approach, namely the inter-temporal budget constraint (IBC) approach in present value terms, has been applied in the study of the sustainability of public finance. It is also referred to as the present value budget constraint (PVBC). This approach is also characterized as the 'solvency condition for sustainable debt' as it highlights that the debt must be repaid. What is required is that the discounted value of the expected future Government surpluses is sufficient to repay the outstanding Government debt. Econometrically, it implies long-run co-movement between revenue and expenditure or the existence of co-integration between the two variables. If the PVBC is not satisfied, then public spending is not sustainable in the long run. That is, if there has been a deficit for some years, a government is expected to run surpluses in the future.

Formal analysis of sustainability of federal finances in India is conspicuous by their absence[3]. The existing results broadly indicate towards unsustainability of state finances in India if the present policies continue. This paper has revisited the issue of sustainability of the State finances in India for a panel of Indian States for the period beginning 1990-91 through 2002-03. Employing non-stationary panel methods, we conduct a formal test to examine whether State finances in India are sustainable, by examining the question from

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[2] The Domar stability condition could be met for all years except 1997-98 during the period 1990-91 to 1998-99. The details of the Domar stability condition are given in Appendix 1.

[3] Formal analysis on sustainability of public finances at various levels of Government is typically done employing tools like trend analysis, time series econometrics and even macro modeling. Such analysis in the previous works is found mainly for the Central Government, all States combined and general Government leaving the panel of states so far out of their purview.

the most straightforward way by asking if States have breached their inter-temporal budget constraint. The inter-temporal budget constraint test of the sustainability of fiscal policy asks whether the past behavior of revenue, expenditure and the fiscal deficit could be continued indefinitely without prompting an adverse response from lenders[4]. While the existing papers have studied co-integration between national government expenditure and revenue, there has been limited attention on federal government finances. This paper attempts to fill this gap. We exploit available data on Indian State government finances and study sustainability of fiscal policy of States in the framework of non-stationary panel methods. Testing for the presence of panel co-integration between state government expenditure and revenues enables us to draw conclusions about the sustainability of State finances.

The rest of the paper is organized as follows. Section II provides a brief review of sustainability of the fiscal policy from the inter-temporal budget constraint angle and formally describes what is meant by a sustainable fiscal policy. The econometric methodology used to test for sustainability is outlined in section III followed by a description of the data. The results from the sustainability exercise are outlined in section IV. Concluding observations follow in section V.

II. Fiscal Sustainability Criteria

Sustainability of government finances has been empirically examined in the literature using various techniques. One of the ways has been to test for co-integration between government expenditure and revenues. In other words, if unsustainable spending and taxing policies of the government leads to violation of the government's inter-temporal budget constraint, the deficit can be sustainable only if government spending is reduced and/or tax revenues increased. This necessitates a co-integration between government spending and revenue (Haikkko and Rush, 1991; Olekalns and Cashin, 2000).

[4] The question of sustainability of the debt involves considerations of whether Ponzi financing arrangements (*i.e.*, the funding of interest payments from the proceeds of new debt issues) has been used as a debt management strategy. In the absence of non-distortionary taxation, a dynamically efficient economy requires that Ponzi financing not be used (Wilcox 1989).

If the present value budget constraint (PVBC) is not satisfied, then public finances are not sustainable in the long run[5]. The issue of inter-temporal budget constraint is typically examined using co-integration analysis. The development of non-stationary econometrics in the time series literature has allowed for a deeper understanding of the statistics of 'long-run steady state' relationships. These relationships were identified as co-integrated relationships among non-stationary variables. However, most of the developments within time series literature have been criticized as having more to do with a particular dataset than economic theory in general. Yet it has been argued that the co-integration literature offers a promising cross-over between economic theory and econometric technique.

Of late, time series methods have been used in the panel framework to test macroeconomic hypotheses on integrated data. Combining time series results on cross-sectional data offers certain advantages. The econometrics of non-stationary panels combines the best of both the worlds – the methods of dealing with non-stationary data from time series and increased data and power from cross section. The argument presented in favour of panel data methods is that they have greater power than standard unit root and co-integration tests, by virtue of the reduction in noise caused by the averaging or pooling across the units of the panel. It has been shown that an added advantage of some of these test statistics is that under the null hypothesis they have Gaussian distributions asymptotically. Inference in large samples is therefore, in some sense, made "standard". Thus as the time and cross-section dimension increase, panel test statistics and estimates can be derived which converge in distribution to normally distributed random variables. Also within the testing framework, the addition of cross-section dimension adds power to the tests. Keeping in view the above results from panel methods, this paper tries to re-assess the state of fiscal sustainability in Indian States employing state-wise data and panel co-integration technique.

[5] The inter-temporal budget constraint (IBC) in present value terms, which is also referred to as the present value budget constraint (PVBC)

III. Empirical Methodology

Sustainability of Government finances has been evaluated by testing to see whether G_{it} and R_{it} form a co-integrating relation in the specification (1).

$$R_{it} = \alpha_i + \beta G_{it} + e_{it} \qquad (1)$$

Where, G_{it} and R_{it} denote government receipts and government expenditures for the i^{th} state at t^{th} time period respectively and $0 < \beta \leq 1$.

A necessary condition for the existence of co-integration is that the individual series are integrated of orders one. Should only one of the series be I(1), with the other being stationary, the two series will permanently diverge and equation (5) will not hold. Theoritically, if Gt and Rt are both I(1) then they must be co-integrated with co-integrating vector [1–1] for sustainability to hold. The same applies when the variables are presented as ratios of GDP. The stationarity of the residuals in a cointegrating relationship restricts the extent to which Gt and Rt can deviate from each other over time. Co-integration implies that there exists an error correction mechanism pushing government finances towards the levels required by the inter-temporal budget constraint. In the absence of co-integration, the error correction mechanism will not operate and there is no likelihood that equation (3) will hold. In these circumstances, we would conclude that under unchanged fiscal policies, debt stock would be unsustainable.

In this study we examine whether the revenue receipts and revenue expenditure share a cointegrating relationship for a panel of States. The variables employed to estimate (1) are revenue[6] receipts and revenue expenditures of 16 States of India for the period 1990-91 to 2001-02. The choice of the terminal year has been guided by the availability of accounts figures (actuals) on receipts and expenditure. The figures have been taken from the budget documents of different State governments. The receipt variable is represented by log of per capita revenue receipts (LPREV) and the expenditure variable by the log of per capita revenue expenditure (LPEXP). Use of time series estimation techniques, to study co-integration is precluded given the small number of observations for estimation.

[6] Another possibility is to study co-integration between total receipts and total expenditure. However, given the greater concern over deficit on the revenue account in the literature, the analysis here is carried out in terms of receipts and expenditure in the revenue account.

However, taking advantage of the panel nature of the data, we employ panel data econometric techniques.

As a starting point, the variables have been first examined for stationarity in a panel context. If the variables are found to contain a unit root, the variables are examined for possible co-integration. In the event there is co-integration between the revenue and expenditure, one can infer that fiscal situation for the States is sustainable. Lack of co-integration on the other hand, would point towards unsustainability of State level Government finances. Specifically, the panel unit root tests developed by Im, Pesaran and Shin (IPS), Fisher's ADF and Breitung t-stat to test for panel unit roots have been employed to test for panel unit roots. Pedroni's method is used to test for panel co-integration. In the event the variables are co-integrated, to get appropriate estimates of the co-integration relationship, efficient estimation techniques are employed. The appropriate estimation method is so designed that the problems arising from the endogeneity of the regressors and serial correlation in the error term are avoided. Due to the corrections, the estimators are asymptotically unbiased. Especially, fully modified ordinary least squares (FMOLS) is applied. In the FMOLS setting, non-parametric techniques are exploited to transform the residuals from the co-integration regression and get rid off nuisance parameters, c.f. Phillips (1995) and Pedroni (2001). The details of these tests have been discussed in the technical Appendix.

IV. Results

The results of these unit root tests for each of our variables are shown in Table-1. In no case the null hypothesis that every state has a unit root for the series in log levels is rejected. However, the series are stationary in their first differences. Hence, the variables considered are I(1).

Table 1: Panel Unit Root Tests

Variable → Statistics ↓	LPREV		LPEXP	
	Levels	**First Difference**	**Levels**	**First Difference**

Im Pesaran and Shin (IPS) W-stat	-0.171 (0.43)	-7.51 (0.00)	1.55 (0.94)	-11.39 (0.00)
ADF- Fisher Chi square	36.57 (0.26)	114.56 (0.00)	16.64 (0.98)	155.02 (0.00)
Breitung t- stat	3.66 (0.99)	-5.01 (0.00)	0.88 (0.81)	-13.35 (0.00)
Note: Figures in brackets indicate p- values.				

Once ascertained that both the variables are I(1), we turn to the question of possible co-integration between them. Table 3 reveals the evidence regarding the co-integration property between revenue receipts and revenue expenditure for the Indian States. The panel co-integration tests suggested by Pedroni (1999) are applied for the entire period of analysis and also for the sub-period 1998-2002(Table-2). Positive value for the panel variance (panel - v) statistic and negative values for all other statistics are obtained for the co-integration test performed for the full period. The panel - v statistics turns out to be positive and rest of the statistics except one turn out to be negative for the sub-period 1998-2002. Thus, in general, the Pedroni (1999) tests turn out to reject the null hypothesis of no co-integration between the variables considered. Panel co-integration during the sub-period 1998-2002 has also been studied for robustness purposes. State finances came under severe pressure consequent to the implementation of the recommendations of the fifth pay commission during this sub period. The rejection of the null of no co-integration for the period 1998-2002 gives further credence to our results.

Table 2: Panel Co-integration Between LPREV and LPEXP

Statistics	Period	
	1991-2002	1998-2002
Panel *v*-statistics	3.94	2.83
Panel ρ-statistics	-5.41	-0.40
Panel *t*-statistics (non-parametric)	-9.17	-3.95
Panel *t*-statistics (parametric)	-8.40	-4.86
Group ρ-statistics	-3.32	1.54
Group *t*-statistics (non-parametric)	-10.35	-5.43
Group *t*-statistics (parametric)	-9.54	-25.48

As per capita revenue and per capita expenditure are co-integrated, Pedroni's FMOLS estimation techniques have been employed to estimate the co-integrating relationship. The co-integrating vector thus obtained is (1, -0.8) which is not very far from the theoretically ideal value for fiscal sustainability[7]. The above analysis goes to indicate unlike the prevalent wisdom, state finances in India might not be unsustainable.

The pooled FMOLS estimate has been used as benchmark to categorise states into relatively sustainable and unsustainable (table-3). As can be seen from table-3, individual FMOLS coefficients for as many as eight states are below the pooled FMOLS estimate, thus relatively unsustainable compared to the rest of the states under study.

Relative Fiscal Sustainability of States	
States that are relatively sustainable	**States that are relatively unsustainable**
Andhra Pradesh, Bihar, Haryana, Himachal Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharastra, Punjab and Tamil Nadu	Assam, Gujurat, Orissa, Rajasthan, Uttar Pradesh and West Bengal
The pooled estimate is the anchor for measuring relative sustainability. States where individual FMOLS estimate is less than the pooled have been categorised as relatively sustainable.	

V. Concluding Observations

In this paper, we have tested the sustainability of government finances at the State level by studying the stationarity and the co-integration properties of per capita expenditures and revenues for sixteen major States of India. On the whole, we find Indian States show sustainable budgetary paths, if one assumes that co-integration of expenditures and revenues is a sufficient condition for fiscal sustainability. Further, the co-integrating vector that is obtained is not very far from the theoretically ideal value. The co-integrating vector reveals that when per capita expenditures increases by 1.0, the per capita revenue

[7] The details of the FMOLS estimates can be found in Appendix 2.

rises by 0.8 on an average. The insensitivity of the result for the sub-period 1998-2002 adds credence to the result that state finances in India are not unsustainable.

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Appendix 1

The Domar stability condition has been defined as:

$$y - r > 0 \quad (1)$$

$$r = (IP)_t / (OD)_{t-1} \quad (2)$$

Where, y = Growth of GDP at current market prices
r = Average interest rate
IP = Interest payment
OD = Outstanding debt
t = Time period

Equation (1) and (2) imply that the debt-GDP ratio (d/y) is stable if the nominal GDP growth (g) exceeds the nominal interest rate (r) on government debt. According to the Domar stability condition, larger the gap between the interest rate and growth rate the higher will be the d/y. Thus, to stabilize debt-GDP ratio (d/y), rate of interest should be lower than the output growth ($r<g$). In this study, the Domar stability condition has been tested in respect to market related borrowings rates and administered interest rates for the States and results are in Table 3. Average interest rate r(S) is calculated as a ratio of interest payment to the previous year's total liability of the States. The second series R(ML)S is the weighted average rate on current loans. The series G(Y) gives the growth rate of GDP at current prices.

Table 3: Domar Condition of Debt Sustainability for States

Year	All States		
	G(y)	**r (S)**	**R(ML)S**
1990-91	16.65	9.19	11.50
1991-92	14.85	9.92	11.84
1992-93	14.58	10.46	13.00
1993-94	14.81	11.11	13.50
1994-95	17.87	12.13	12.50
1995-96	17.30	11.89	14.00
1996-97	15.17	12.05	13.82
1997-98	11.28	12.37	12.82
1998-99	14.35	12.76	12.35
1999-00	11.25	13.21	11.89
2000-01	8.64	12.31	10.99
2001-02	9.11	12.95	9.20

Appendix 2: Individual and Pooled FMOLS Estimates

State	FMOLS estimates
Andhra Pradesh	0.91 (-1.59)
Assam	0.75 (-2.28)
Bihar	0.82 (-1.41)
Gujarat	0.78 (-4.61)
Haryana	0.77 (-2.76)
Himachal Pradesh`	0.83 (-2.66)
Karnataka	0.86 (-2.64)
Kerala	0.82 (-3.02)
Maharashtra	0.75 (-3.72)
Madhya Pradesh	0.82 (-5.20)
Orissa	0.74 (-4.38)
Punjab	0.82 (-1.73)
Rajasthan	0.71 (-4.40)
Tamilnadu	0.97 (-0.43)
Uttar Pradesh	0.74 (-2.63)
West Bengal	0.7 (-5.80)
Pooled	0.80 (-12.31)

Technical Appendix

Tests with Individual Unit Root Processes

The Im, Pesaran, and Shin, and the Fisher-ADF tests all allow for individual unit root processes so that may vary across cross-sections. The tests are all characterized by the combining of individual unit root tests to derive a panel-specific result.

Im, Pesaran, and Shin (IPS) Test

Im, Pesaran, and Shin begin by specifying a separate ADF regression for each cross section:

$$\Delta y_{it} = \alpha y_{it-1} + \sum_{j=1}^{p_i} \beta_{ij} \Delta y_{it-j} + X'_{it}\delta + \epsilon_{it} \qquad (1)$$

The null hypothesis may be written as,

$$H_0\colon\ \alpha_i = 0, \text{ for all } i \qquad (2)$$

while the alternative hypothesis is given by:

$$H_1\colon \begin{cases} \alpha_i = 0 & \text{for } i = 1, 2, \dots, N_1 \\ \alpha_i < 0 & \text{for } i = N+1, N+2, \dots, N \end{cases} \qquad (3)$$

After estimating the separate ADF regressions, the average of the t-statistics for α_i from the individual ADF regressions

$t_{iT_i}(p_i)$:

$\bar{t}_{NT} = \left(\sum_{i=1}^{N} t_{iT_i}(p_i) \right) / N$ is then adjusted to arrive at the desired test statistics.

Fisher-ADF

An alternative approach to panel unit root tests uses Fisher's (1932) results to derive tests that combine the p-values from individual unit root tests. This idea has been proposed by Maddala and Wu, and by Choi.

If we define πi as the p-value from any individual unit root test for cross-section , then under the null of unit root for all N cross-sections, we have the asymptotic result as:

$$-2 \sum_{i=1}^{N} \log(\pi_i) \rightarrow \chi^2_{2N} \qquad (4)$$

In addition, Choi demonstrates that:

$$Z = \frac{1}{\sqrt{N}} \sum_{i=1}^{N} \Phi^{-1}(\pi_i) \rightarrow N(0, 1) \quad (5)$$

where Φ^{-1} is the inverse of the standard normal cumulative distribution function.

Panel cointegration

There are four tests of the null hypothesis of no co-integration in panel data with varying intercepts and varying slopes. These are Wu and Yin (1999) average ADF test for varying slopes, Phillips and Ouliaris (1990) average Phillips statistic for varying slopes, Pedroni (1995, 1997) test and McCoskey and Cao (1998) test. Of these, we use Pedroni's panel co-integration test, which allows for heterogeneous co-integrating vectors. The panel co-integration tests suggested by Pedroni (1999) extend the residual based Engle and Granger (1987) co-integration strategy. First, the co-integration equation is estimated separately for each panel member. Second, the residuals are examined with respect to the unit root feature. If the null of no co-integration is rejected, the long run equilibrium exists, but the co-integration vector may be different for each cross section. Also, deterministic components are allowed to be individual specific. To test for co-integration, the residuals are pooled either along the within or the between dimension of the panel, giving rise to the panel and group mean statistics (Pedroni, 1999). In the former, the statistics are constructed by summing both numerator and denominator terms over the individuals separately, while in the latter, the numerator is divided by the denominator prior to the summation. Consequently, in the case of the panel statistics the autoregressive parameter is restricted to be the same for all cross sections. If the null is rejected, the variables in question are co-integrated for all panel members. In the group statistics, the autoregressive parameter is allowed to vary over the cross section, as the statistics amounts to the average of individual statistics. If the null is rejected, co-integration holds at least for one individual. Therefore, group tests offer an additional source of heterogeneity among the panel members.

Both panel and group statistics are based on augmented Dickey Fuller (ADF) and Phillips-Perron (PP) method. Pedroni (1999) suggests 4 panel and 3 group statistics. Under appropriate standardization, each statistic is distributed as standard normal, when both the cross section and the time series dimension become large. The asymptotic distributions can be stated in the form

The asymptotic distributions can be stated in the form

$$Z = \frac{Z^{*} - \mu\sqrt{N}}{\sqrt{\nu}} \qquad (6)$$

where Z^* is the panel or group statistic, respectively, N the cross section dimension and μ and ν arise from of the moments of the underlying Brownian motion functionals. They depend on the number of regressors and whether or not constants or trends are included in the co-integration regressions. Estimates for μ and ν are based on stochastic simulations and are reported in Pedroni (1999). Thus, to test the null of no co-integration, one simply computes the value of the statistic so that it is in the form of (2) above and compares these to the appropriate tails of the normal distribution. Under the alternative hypothesis, the panel variance statistic diverges to positive infinity, and consequently the right tail of the normal distribution is used to reject the null hypothesis. Consequently, for the panel variance statistic, large positive values imply that the null of no co-integration is rejected. For each of the other six test statistics, these diverge to negative infinity under the alternative hypothesis, and consequently the left tail of the normal distribution is used to reject the null hypothesis. Thus, for any of these latter tests, large negative values imply that the null of no co-integration is rejected. The intuition behind the test is that using the average of the overall test statistic allows more ease in interpretation: rejection of the null hypothesis means that enough of the individual cross sections have statistics 'far away' from the means predicted by theory were they to be generated under the null.

Panel FMOLS

In the event the variables are co-integrated, to get appropriate estimates of the co-integration relationship, efficient estimation techniques are employed. The appropriate estimation method is so designed that the problems arising from the endogeneity of the regressors and serial correlation in the error term are avoided. Due to the corrections, the estimators are asymptotically unbiased. Especially, fully modified (FMOLS) is applied. In the model

$$y_{it} = \alpha_i + \beta_i x_{it} + u_{it}$$

$$x_{it} = x_{it-1} + \varepsilon_{it} \quad , \varpi_{it} = (u_{it}, \varepsilon_{it})' \qquad (7)$$

the asymptotic distribution of the OLS estimator depends on the long run covariance matrix of the residual process w. This matrix is given by

$$\Omega_i = \lim_{T\to\infty} \frac{1}{T} E\left(\sum_{t=1}^{T} \varpi_{it}\right)\left(\sum_{t=1}^{T} \varpi_{it}\right)' = \Sigma_i + \Gamma_i + \Gamma_i' = \begin{pmatrix} \varpi_{u,i} & \varpi_{u\varepsilon,i} \\ \varpi_{u\varepsilon,i} & \varpi_{\varepsilon,i} \end{pmatrix} \quad (8)$$

for the *i*-th panel member, where

$$\Sigma_i = \lim_{T\to\infty} \frac{1}{T} \sum_{t=1}^{T} E\left(\varpi_{it}\varpi_{it}'\right) = \begin{pmatrix} \sigma_{u,i}^2 & \sigma_{u\varepsilon,i} \\ \sigma_{u\varepsilon,i} & \sigma_{\varepsilon,i}^2 \end{pmatrix}$$

$$\Gamma_i = \lim_{T\to\infty} \frac{1}{T} \sum_{k=1}^{T-1} \sum_{t=k+1}^{T} E\left(w_{it} w_{it-k}'\right) = \begin{pmatrix} \gamma_{u,i} & \gamma_{u\varepsilon,i} \\ \gamma_{u\varepsilon,i} & \gamma_{\varepsilon,i} \end{pmatrix} \quad (9)$$

denote the matrices of contemporaneous correlation coefficients and the auto-covariance, respectively, where the latter are weighted according to the Newey and West (1994) proposal. For convenience, the matrix

$$\Theta_i = \begin{pmatrix} \theta_{u,i} & \theta_{u\varepsilon,i} \\ \theta_{\varepsilon u,i} & \theta_{\varepsilon,i} \end{pmatrix} = \Sigma_i + \Gamma_i = \sum_{j=0}^{\infty} E(w_{ij} w_{i0})' \quad (10)$$

is defined. The endogeneity correction is achieved by the transformation

$$y_{it}^* = y_{it} - \hat{\varpi}_{u\varepsilon,i} \hat{\varpi}_{\varepsilon,i}^{-1} \Delta x_{it} \quad (11)$$

mator is

$$\hat{\beta}_i^* = (X_i' X_i)^{-1} (X_i' y_i^* - T\hat{\theta}_{\varepsilon u}^*) \quad (12)$$

where, $\hat{\theta}_{\varepsilon u}^* = \hat{\theta}_{\varepsilon u} - \hat{\theta}_{\varepsilon} \hat{\varpi}_{\varepsilon,i}^{-1} \hat{\varpi}_{\varepsilon u,i}$

provides the autocorrelation correction. The estimates needed for the transformations are based on OLS residuals obtained in a preliminary step. The panel FMOLS estimator is just as the average of the individual parameters (Pedroni, 2001).