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ABSTRACT

In this paper, the elasticities of substitution between capital and labour inputs are estimated for the 15 major sectors that together comprise the entire Indian economy. The estimation is based on a constant elasticity of substitution (CES) production function, using annual time series data for the period between 1980–81 and 2008–09. Seven sets of estimates of the elasticity of substitution have been made using alternative specifications of the model and econometric techniques of estimation of parameters. The results indicate that the elasticity of substitution is less than unity in most sectors of the Indian economy, and that the elasticity of substitution is less in manufacturing than that in the services sector. There are indications of significant labour-saving technical change in both manufacturing and services sectors. There is a clear downward trend in labour income share in value added in the manufacturing sector during 1980–2008, which seems to be attributable, at least partly, to labour-saving technical change.

Keywords: CES production function, SMAC function, Kmenta approximation, Non-linear estimation, ARDL model, Elasticity of substitution, Factor-augmenting technical change

JEL codes: C180, C510, L6, L7, L8, L9, O14

1 INTRODUCTION

In developing countries, capital accumulation is often the prime source of economic growth. For rapidly growing developing countries such as India and China, the growth rate in capital input is, commonly, well above the growth rate in labour input. In India, for instance, the trend growth rate in net capital stock between 1980–81 and 2009–10 was 5.9 per cent per annum, whereas the trend growth rate in employment during this period was about 1.8 per cent per annum.[1] The situation in China is quite similar. The average annual growth rate in capital input in the Chinese economy between 1979 and 2007 was about 8.6 per cent, and the average annual growth rate in labour input was much lower at about 1.6 per cent.[2]

The fact that economic growth in rapidly growing developing countries is commonly characterised by a steeply rising capital–labour ratio implies that diminishing returns to capital input may pose a challenge to the sustainability of growth. How serious this problem will turn out to be depends crucially on the elasticity of substitution between capital and labour. If the elasticity of substitution between capital and labour is high, meaning thereby that labour can easily be substituted by capital, it may be possible to sustain a relatively high rate of economic growth even in the face of increasing capital intensity of production. Thus, the elasticity of substitution between capital and labour is a crucial parameter for the sustainability of economic growth, making it important to study.

Attention may be drawn here to the paper by de La Grandville (1989), which shows theoretically that the growth rate of income per capita bears a positive relationship with the elasticity of substitution between capital and labour at any stage of an economy's development. This hypothesis has been tested empirically by Mallick (2007) by applying cross-country regression analysis. He uses country-wise data on the rate of economic growth and country specific estimates of elasticity of substitution at the aggregate economy level. He finds that the elasticity of substitution has a significant positive effect on the growth rate in GDP per capita, upholding de La Grandville's hypothesis. According to Mallick's econometric results, the difference in the elasticity of substitution explains about 30 per cent of the growth differential between East Asia and Sub-Saharan Africa. Evidently, the econometric evidence presented by Mallick (2007) brings out the importance of the elasticity of substitution for sustaining a high rate of economic growth.

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[1] Estimated trend growth rate in net capital stock is based on the estimates of net capital stock given in the National Accounts Statistics (Central Statistical Office, Government of India). Estimated trend growth rate in employment is based on estimates of aggregate employment in India based on employment–unemployment surveys of the NSSO (National Sample Survey Office, Government of India).

[2] This is based on the growth rates in input and output in the Chinese economy presented in Whalley and Xing (2012).

It should be pointed out here that the influence of the economy-level capital–labour substitution elasticity on the growth process is conditioned by the extent and nature of inter-sectoral shifts in resources. As labour moves from low-productivity sectors to higher productivity sectors, facilitated by capital accumulation, the aggregate-level productivity would increase, which may neutralise the consequences of diminishing returns to capital input, and thus permit the growth process to sustain over time. Another important factor that plays a role in the growth process is the degree of labour-saving bias in technical change. A strong labour-saving bias in technical change will prevent the marginal productivity of capital from falling even in the face of growing capital intensity of production and thus contribute to sustained economic growth. It follows from the above that the sustainability of economic growth in a developing economy that is experiencing rapid capital accumulation will depend on (1) the elasticity of substitution between capital and labour in different sectors of the economy; (2) changes in inter-sectoral resource allocation (caused by differential income elasticity of different products and other factors such as growing possibilities of international trade);[3] and (3) the labour-saving bias of technical change.

The above discussion has brought out clearly the significance of the capital–labour substitution elasticity in the growth process. An empirical study of the elasticity of substitution in different sectors of the economy is therefore important for understanding the growth process. Yet, this aspect has received scant attention in the empirical economic literature. This applies also to empirical studies done for India. As discussed in the next section, there has been hardly any recent study of elasticity of substitution between capital and labour for different sectors of the Indian economy, although currently a major issue before India is how to achieve a rapid economic growth and sustain the growth rate over time.

A study of elasticity of substitution is important not only for its role in the growth process, but also for the implications it has for inter-temporal changes in the income share of labour and capital. In many countries, there has been a downward trend in the income share of labour in value added. This is true also for India (Goldar 2013). Under competitive conditions, a downward trend in labour income share can arise from greater than unitary elasticity of substitution between capital and labour, and if the elasticity is not above 1, this may be caused by labour-saving bias of technical change. Clearly, an empirical study of elasticity of substitution in different sectors of the Indian economy coupled with assessment

[3] A theoretic model of Alvarez-Cuadrao and Long (2011) suggests the elasticity of substitution between capital and labour in different sectors of the economy may partly explain the structural change in the economy. (They note that other factors influencing structural change are income elasticity of demand, differential productivity growth, and differential factor intensity and capital deepening.)According to the results of their analysis, as the economy grows, the fraction of capital (labour) allocated to the sector with high elasticity of substitution increases (decreases).

of the extent of bias in technical change would be helpful in understanding the observed trends in factor income shares.

In this paper, the elasticities of substitution are presented for the 15 major sectors that together comprise the entire Indian economy. The significance of the estimates of elasticity of substitution has already been indicated above and does not require reiteration. There is, however, an additional point about the estimates of elasticity of substitution that warrants attention. Non-availability of comparable estimates of the elasticity of substitution between capital and labour for different sectors of the Indian economy (based on data covering the same period and the use of the same methodology for the estimates for different sectors of the economy) has been a major difficulty in the construction of computable general equilibrium (CGE) models for the India economy. This has compelled such models to either use old estimates for certain sectors of the Indian economy or draw on the elasticity estimates for other countries. The estimates of elasticity of substitution presented in the paper should therefore be useful for CGE studies for India.

The paper is organised as follows. The next section quickly reviews earlier studies in which estimates of elasticity of substitution were presented for the Indian economy. Section 3 outlines the objective and scope of the study. Section 4 discusses data and methodology. Section 5 presents the estimates of elasticity of substitution. Finally, Section 6 summarises and concludes.

2 EARLIER ESTIMATES OF CAPITAL–LABOUR SUBSTITUTION ELASTICITY IN THE INDIAN ECONOMY

Several production function studies were undertaken in the Indian context in the 1970s and 1980s (for example, Shankar 1970; Narasimham and Fabrycy 1974). These studies provided estimates of the elasticity of substitution between capital and labour in the manufacturing industries. Subsequently, there have been very few such studies. Chadha and others (1995) undertook a study of the elasticity of substitution in India, but it was confined to the manufacturing industries, and did not cover other sectors of the Indian economy. Although one can find some recent estimates of the elasticity of substitution between capital and labour in the Indian manufacturing industries (for example, Virmani and Hashim 2009), there is probably no recent study in which estimates of elasticity of substitution are provided for other sectors of the Indian economy.

There have been some multi-country or cross-country studies on the elasticity of substitution between capital and labour in which India is included. It would be useful to discuss here briefly the results obtained in some of these studies. Mallick (2007) has estimated the elasticity of substitution at the aggregate economy level separately for different countries.

He has used a normalised constant elasticity of substitution (CES) production function for obtaining an estimate of σ, the elasticity of substitution. Time series data (1950 to mid-1990s, or a later year up to 2000) have been used for different countries and non-linear least squares has been is applied to get an estimate of σ. The estimates of σ obtained in Mallick's study for some major developing countries are as follows: 0.515 for India, 0.548 for China, 0.112 for Argentina, 0.126 for Brazil, 0.087 for Mexico, 0.197 for Thailand, 0.075 for Philippines, 1.139 for Indonesia, and 1.522 for Malaysia. The estimates suggest that the elasticity of substitution between capital and labour at the aggregate economy level is generally low among developing countries. In particular, the estimates indicate that at the aggregate level, the elasticity of substitution between capital and labour is only about 0.5 in India.

Fragiadakis et al. (2012) have used pooled time series (1995–2009) and cross-section data to estimate elasticity of substitution. They group the countries into three regions. One of the groups considered by them includes China, India, and Japan, and the estimates obtained for this region are relevant to this paper. Fragiadakis et al. base their analysis on the CES production function and, unlike the paper of Mallick mentioned above, base their regression equations on the relationships between productivity and factor prices arising from the conditions of profit maximisation. They have presented estimates of elasticity of substitution for six broad sectors of the economy. Both short-term and long-term estimates of elasticity of substitution are presented. Their estimates of elasticity of substitution for the region comprising China, India, and Japan are shown in Table 1.

Table 1 Estimates of elasticity of substitution between capital and labour for the region that includes China, India, and Japan by sectors

Sector	Short-run elasticity	Long-run elasticity
Agriculture	0.14–0.47	1.92
Mining, quarrying, and manufacturing	0.42–0.71	0.82
Energy	0.53–0.75	1.2–1.4
Construction	0.21–0.79	1.6–2.3
Market services	0.34–0.86	1.1–1.2
Non-market services	0.09–0.93	NA

Source: Based on estimates presented in Fragiadakis et al. (2012). They have presented several estimates using alternate specification of the model. Hence, the range of estimates obtained is shown in the table.

It is interesting to observe that the short-run elasticity of substitution is low (which is consistent with the estimates of Mallick at the aggregate economy level: 0.515 for India, 0.548 for China, and 0.331 for Japan), and in some cases it is very low. On the other hand, the long-run elasticity of substitution is more than 1 in most cases.

Dissanayake and Sim (2010) have used panel data for 82 countries for estimating the CES production function. As Mallick (2007), they have estimated the CES production function directly but, unlike him, have used a first order Taylor expansion of the CES function, making the equation linear in parameters. Their estimate of the elasticity of substitution is in the range of 1.4 to 2.3. Their analysis brings out heterogeneity among countries concerning production function parameters. The countries in the lower quantiles of income distribution have higher elasticity of substitution. Although an estimate of elasticity of substitution for India is not presented in the paper, the results suggest that the elasticity of substitution is in general more than unity, and the elasticity of substitution in India is higher than those in developed countries. Thus, the estimates of Dissanayake and Sim (2010) are at variance with the estimates of Mallick (2007) and Fragiadakis et al. (2012). This might be due to the methodology of estimation employed (particularly the use of Taylor expansion).

Wang (2012) has estimated the CES production function for India and China using panel data (using a Taylor series approximation to the CES function, as in the study of Dissanayake and Sim). Provincial level panel data are used for China and state-level panel data for India. Data for India has been taken from Ghate and Wright (2012). The estimated elasticity of substitution is about 0.82 to 0.85 for India and 0.87 to 0.91 for China. The estimated elasticity of substitution for India is found to be less than 1, as in the study of Mallick (2007) noted above.

3 OBJECTIVE AND SCOPE OF THE STUDY

The objective of this study is to estimate the elasticity of substitution between capital and labour inputs for major sectors of the Indian economy. The estimation of the elasticity of substitution is based on a CES production function using annual time series data for the period between 1980–81 and 2008–09, for 15 major sectors of the Indian economy (Table 2).

Table 2 Major sectors covered in the study

Sr. No.	Sector
1	Agriculture, including livestock
2	Forestry and logging
3	Fishing
4	Mining and quarrying
5	Manufacturing
6	Electricity, gas, and water supply
7	Construction
8	Trade

contd.

Table 2 Major sectors covered in the study (contd.)

Sr. No.	Sector
9	Hotels and restaurants
10	Railways, transport by other means and storage
11	Post and communication
12	Banking and insurance
13	Real estate, ownership of dwellings, and business services
14	Public administration and defence
15	Other services

The choice of the sectors is largely dictated by the availability of data in the National Accounts Statistics (NAS), the prime source of data for this study, brought out by the Central Statistical Office (CSO), Government of India (GoI).

4 DATA AND METHODOLOGY

As stated above, the estimation of the elasticity of substitution between capital and labour input in major sectors of the Indian economy has been done from annual time series data for the period 1980–81 to 2008–09. It is assumed that the production technology in various sectors of the Indian economy can be characterised by a CES production function. A two-input production function framework underlies the elasticity estimates. Gross value added at constant prices is taken as output. Capital and labour are taken as the two inputs. Further details on data and methodology are provided below.

4.1 Data

The main source of data for the study is the NAS brought out by the CSO, GoI. The 1999–2000 NAS series is used for the analysis. To estimate the parameters of the CES function, time series data are needed on output (measured by real gross value added), capital input (measured by net capital stock at constant prices), and labour input (measured by an index of labour input formed on the basis of estimated number of persons employed). The methodology employed in this study to estimate the CES function parameters also needs a time series on labour income deflated by the cost of living index. Further details on the construction on time series on output, inputs, and factor incomes are provided below.

Output For output, Gross Domestic Product (GDP) by economic activity at constant prices (i.e. at 1999–2000 prices) has been used. This is available in the NAS.

Capital For capital input, net capital stock by industry of use (closing stock, as on 31 March) at 1999–2000 prices has been used. This is available in the NAS.

Labour Labour input series has been formed in two steps. In the first step, NSSO data on employment (major rounds) have been used to form an index of employment for the selected 15 major sectors of the Indian economy for five years: 1983–84, 1987–88, 1993–94, 1999–2000, and 2004–05**.**These are the years for which the major rounds of employment–unemployment survey of the NSSO were undertaken**.** The index is formed with 1983–84 as the base year. In the second step, the employment index obtained for five years have been interpolated or extrapolated using deflated labour income series. The method of construction of labour and capital income series is explained below. The estimated labour income series has been deflated by the consumer price index (CPI) and the deflated series so obtained (which provides an alternative estimate of year-to-year employment growth) is used for interpolation/extrapolation.

Labour and capital income series Data on factor income and depreciation for period 1980-81to 2008-09 provided in the NAS have been used for generating the series of labour and capital income (out of gross value added). The NAS provides estimates of factor incomes for organised and unorganised sector components of different economic activities. For the organised sector component of each economic activity, income of labour (compensation for employees), and income of capital (operating surplus) are directly given in the NAS. In the case of the unorganised sector component of an economic activity, factor incomes are shown under three heads: compensation of employees, operating surplus, and mixed income. The third head, i.e. mixed income, clubs incomes of capital and labour. To separate the incomes of labour and capital, the reported mixed income has to be broken up into the labour and capital income components. In most cases, the mixed income of unorganised sectors has been split according to the ratio of compensation of employees and operating surplus of the organised sector (as has been done in the studies of Golin 2002 and Varma 2008). For three major sectors—(1) agriculture including livestock, (2) forestry and logging, and (3) fishing—a different procedure has been followed, since the organised sector component is small and the ratio observed for the organised sector may not be applicable to the unorganised sector. For these sectors, the mixed income for 2002–03 has been divided into labour and capital income to match the factor income share ratio in gross value added obtained from the social accounting matrix (SAM) for India, 2002–03 prepared by Pradhan et al. (2006). The proportion of labour and capital income out of mixed income computed for 2002–03 for the three sectors mentioned above has then been applied to other years.

Having obtained labour income and operating surplus series for each of the 15 selected sectors from the data on factor incomes from the NAS, depreciation is added to the operating surplus series to form capital income, so that labour and capital income add up to gross value added. After obtaining the labour income series as described above, labour income has been deflated by the consumer price index.[4] The deflated labour income series has then been used to interpolate/extrapolate the previously mentioned employment index available for five years, constructed with the help of the results of employment–unemployment survey (major rounds) of the NSSO.

Labour income share has been computed as the ratio of labour income at current prices (as explained above) to gross value added at current prices. Capital income share is obtained as 1 minus labour income share.

Real product wage and return to capital In most of the models estimated, time series data are needed on the real product wage rate and the real rental received by capital. These are obtained as follows:

W = (GVA at constant prices × income share of labour in gross value added)/ labour input index.

R = {GVA at constant prices × (1-income share of labour in gross value added)}/ net capital stock at constant prices.

Having computed real product wage rate, W, and the real rental of capital input, denoted by R, the wage–rental ratio has been obtained as W/R.

4.2 Econometric Methodology

The studies on elasticity of substitution undertaken in the last 10 years or so have almost uniformly employed the CES production function (see, for example, Mallick 2007; Fragiadakis et al.2012; Whalley and Xing 2012; Duffy and Papageorgiou 2000; and Dissanayake and Sim 2010). Some of them have estimated the CES production function parameters directly, while others have estimated an equation based on the marginal productivity conditions to obtain an estimate of the elasticity of substitution. In this study, both approaches have been taken and seven alternative sets of estimates of elasticity of substitution have been obtained. This is explained further below.

The mathematical expression of the CES production function is

$$Y = Ae^{\lambda t}\left[\delta K^{-\rho} + (1-\delta)L^{-\rho}\right]^{\frac{-\nu}{\rho}} \qquad \text{... (1)}$$

where Y, K, L and t represent output, capital, labour and time respectively and A, λ, δ, ρ and ν are parameters. The return to scale parameter is ν and the elasticity of substitution parameter, σ, is related to ρ by the equation: $\sigma = [1/(1+\rho)]$. In equation (1), λ is the rate of (Hicks-neutral) technical change.

Under the assumption of constant return to scale and perfect competition, one can derive the following two equations which are based on the marginal productivity conditions.

[4] An implicit assumption is that year-to-year variations in wage rate largely reflect the change in the consumer price index. This is not an unrealistic assumption, because several studies undertaken on determination of wages in India have found that the consumer price index is an important determinant.

$$\log\left(\frac{Y}{L}\right) = \sigma \log\left[A^{\rho}(1-\delta)^{-1}\nu^{-1}\right] + \sigma \log W + (\sigma\rho\lambda)t \quad \text{.... (2)}$$

$$\log\left(\frac{Y}{K}\right) = \sigma \log\left[A^{\rho}(1-\delta)^{-1}\nu^{-1}\right] + \sigma \log R + (\sigma\rho\lambda)t \quad \text{.... (3)}$$

In these equations, W and R represent real product wage rate and real product rental rate respectively. These equations will hereafter be called the SMAC functions. The two equations can be estimated jointly by using the seemingly unrelated regression estimate (SURE) method. The coefficient of log(W) in equation (2) and the coefficient of log(R) in equation (3) should be equal, and this condition should be imposed while estimating equations (2) and (3) jointly by the SURE method. The same applies to the coefficient of time variable in these two equations.

A disadvantage of the method based on marginal productivity conditions is that it requires the assumption of perfect competition. An alternative is to estimate the CES function directly by the non-linear least squares method, i.e. directly estimate equation (1) given above. This, however, may prove computationally difficult. An easier alternative is to make the equation linear with the help of the Kmenta approximation The equations to be estimated using the Kmenta approximation are:

$$\log Y = \log A + \lambda t + \nu\delta \log L + \nu(1-\delta)\log K - \left(\frac{1}{2}\right)\rho\nu\delta(\log L - \log K)^2 \quad \text{....(4)}$$

$$\log\left(\frac{Y}{K}\right) = \log A + \lambda t + \delta(\log L - \log K) - \left(\frac{1}{2}\right)\rho\delta(\log L - \log K)^2 \quad \text{... (5)}$$

Equation (5) imposes the assumption of constant return to scale. Equation (4) does not make any such assumption, and give the estimate of the returns to scale parameter. While the Kmenta approximation has the advantage that the resultant equation can be estimated by the ordinary least squares (OLS) method, the estimate of elasticity of substitution obtained by this method suffers from certain biases (see Thursby and Lovell 1978).

Since considerable difficulties were faced in directly estimating the CES function by non-linear least squares, the parameters have been estimated after dropping the time variable (i.e. implicitly assuming λ=0) and assuming constant returns to scale (i.e. assuming ν =1). These assumptions get relaxed when the equations based on Kmenta approximation (equations 4 and 5) are estimated.

The discussion on methodology above has not considered two issues: (1) non-neutral technical change; and (2) non-stationarity of time series. To address the first issue, a factor augmentation form of the CES production function is considered. This gives rise to equations similar to (2) and (3) above except that the coefficients of time in the two equation are not equal. Under the assumption of constant returns to scale, the equations to be estimated are obtained as:

$$\log\left(\frac{Y}{L}\right) = \sigma \log\left[A^{\rho}(1-\delta)^{-1}\nu^{-1}\right] + \sigma \log W + (\sigma\rho\lambda_1)t \qquad \text{....(6)}$$

$$\log\left(\frac{Y}{K}\right) = \sigma \log\left[A^{\rho}(\delta)^{-1}\nu^{-1}\right] + \sigma \log R + (\sigma\rho\lambda_1)t \qquad \text{....(7)}$$

In these equations, λ_L and λ_K are the rates of labour augmenting and capital augmenting technical change. Thus, an alternative set of estimates of the elasticity of substitution has been obtained by estimating equations (6) and (7) by the SURE method, imposing the constraint that the coefficient of log(W) in equation (6) is equal to the coefficient of log(R) in equation (7), but not imposing any restriction on the coefficients of the time variable. Given the estimate of the estimated coefficients of equations (6) and (7), the rates of labour augmenting and capital augmenting technical change can be obtained.

As regards the issue of non-stationarity, Dickey-Fuller test and Augmented Dickey-Fuller test have been done to ascertain the order of integration of the time series on log(Y/L), log(W), log(Y/K), and log(R). Then, equations (6) and (7) have been estimated separately by applying the auto-regressive distributed lag (ARDL) model. The estimated models give an estimate of the long run coefficients. Also, this approach makes it possible to test for co-integration.

The Dickey-Fuller and Augmented Dickey-Fuller test results for each of the 15 major sectors of the economy are presented in the annexure (not discussed in detail in the paper). Suffice it to note that, in general, the test results indicate that the four series, log(Y/L), log(W), log(Y/K) and log(R), are integrated of order 1, i.e. the series are I(1). Accordingly, one would be justified in applying the ARDL model to equations (6) and (7) for estimation of parameters. In certain cases, however, the tests do not clearly establish that the series are integrated of order 1 or of order 0. The use of the ARDL model in those cases can be questioned. From the test results, it appears that the order of integration is neither 1 nor 0 in the cases log(K/Y) and log(R) series for fishing, log(Y/K) series or mining and quarrying, and log(R) series for public administration and defence. Estimation of equation (7) by applying the ARDL model has therefore not been done in these three cases.

5 EMPIRICAL RESULTS

5.1 Preliminary Analysis

Before proceeding to the results of the econometric analysis, it would be useful to present some preliminary analysis of the data. shows the annual trend growth rates in output, capital stock, and labour input during 1980–81 to 2008–09 in the 15 selected major sectors of the economy. Relatively high growth rates in output are observed for post and communication, and banking and insurance, which are the sectors that had relatively faster growth rate also in capital input Table 3.

Table 3 Trend growth rates in output, capital stock, labour input, real product wage rate, real product rental rate and wage-rental ratio for major sectors of the Indian economy, 1980–81 to 2008–09

Sector	**Trend growth rate**					
	Output	Capital Stock	Labour Input	Real Product wage Rate	Real Product Renal Rate	Wage-Rental Ratio
Agriculture, including livestock	2.95	2.47	1.49	1.81	0.05	1.76
Forestry and logging	1.03	3.27	2.02	-0.65	-2.52	1.92
Fishing	5.08	11.63	1.68	4.16	-6.67	11.59
Mining and quarrying	5.37	5.71	1.42	3.09	0.29	2.80
Manufacturing	6.10	7.35	2.98	0.85	0.13	0.73
Electricity, gas and water supply	6.93	5.52	1.24	4.94	1.76	3.13
Construction	5.99	8.38	5.93	-0.45	-0.08	-0.37
Trade	7.14	4.42	4.28	2.85	2.52	0.32
Hotels and restaurants	8.54	6.54	4.77	1.40	3.92	-2.42
Railways, transport by other means and storage	6.52 14.24	5.05 9.92	4.46 7.08	1.52 4.94	2.11 5.74	-0.58 -0.76
Post and communication						
Banking and insurance	9.75	11.61	3.55	3.90	-0.01	3.91
Real estate, ownership of dwellings and business services	7.25	4.68	8.33	-1.50	2.58	-3.98
Public administration and defence	5.66	4.42	0.13	5.63	0.55	5.06
Other services	6.36	8.39	2.50	2.90	-1.61	4.58
All sectors	5.76	5.43	2.10	2.40	2.70	-0.29

The real estate and business services sector has a high rate of growth in employment, but the growth rate of capital stock was not very high. This is the only sector where growth rate of employment significantly exceeded the growth rate of capital stock, i.e. capital–labour ratio had been falling.

Table 3 also shows the trend growth rate in real product wage rate, real rental received by capital, and wage-rental ratio of capital in major sectors of the Indian economy. There was an upward trend in the real product wage rate in most sectors of the Indian economy, particularly in fishing, electricity, gas and water supply, post and communication, banking and insurance, and public administration and defence. It is interesting to observe that the real rental of capital also had an upward trend in most sectors of the economy, particularly in hotels and restaurants, and post and communication. The wage–rental ratio has been on the rise in most sectors of the Indian economy. The fastest increase is observed for fishing, followed by public administration and defence, 'other services', banking and insurance, and electricity, gas, and water supply. Interestingly, the growth rate of real rental has been faster than the growth rate in real wages in four of the eight sectors that comprise the aggregate services sector.

One would expect the direction of change in capital–labour ratio and wage–rental ratio to match, since an increase in the relative labour cost should encourage factor substitution and thus raise capital-labour ratio. Indeed, in most cases, the trend growth in capital–labour and wage–rental ratio is positive. This may be seen from Table 3. A graphic presentation of trends in capital-labour ratio and wage-rental ratio in some of the major sectors of the economy is made in Figures 1–8. The variables are taken in logarithms, so that the slope shows the growth rate. It is seen from the figures that the trends in two variables match in the cases of agriculture; manufacturing; banking and insurance; and real estate, ownership of dwellings and business services. However, in the other four cases considered, the trends do not match. Rather, the capital–labour ratio and wage-rental ratio are found to be moving in opposite directions. This is probably a sign of significant, biased technical change.

Figure 1 Trends in K/L and W/R in agriculture (including livestock)

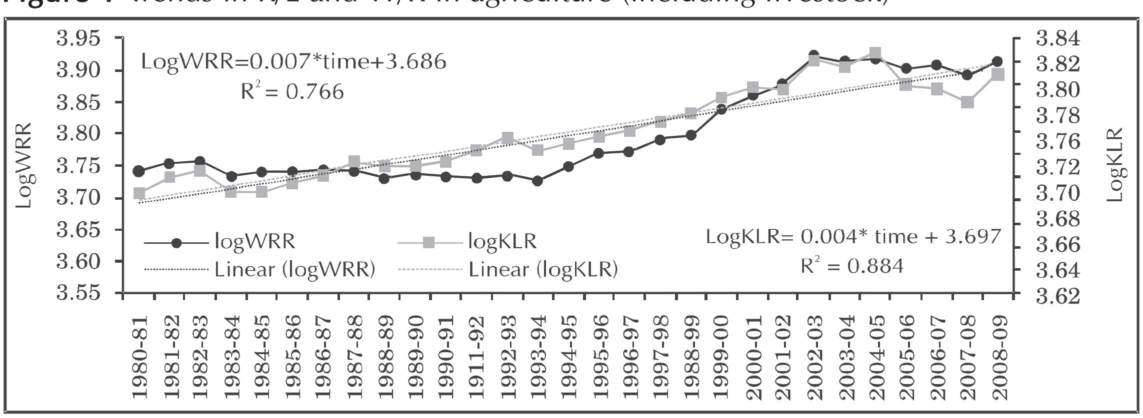


Figure 2 Trends in K/L and W/R in manufacturing

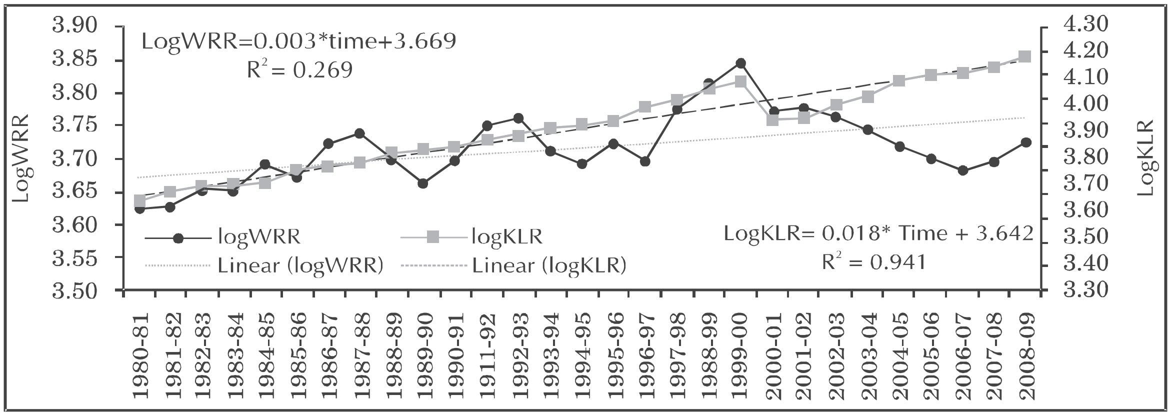


Figure 3 Trends in K/L and W/R in banking and insurance

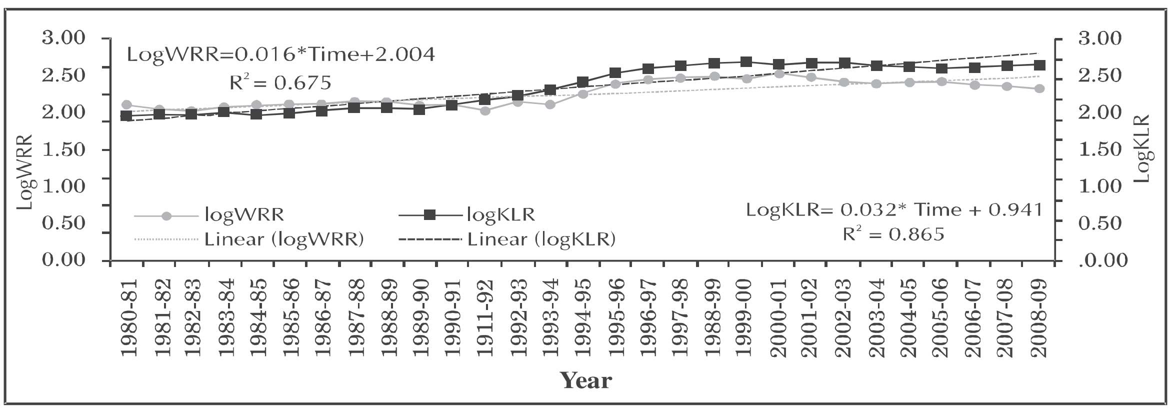


Figure 4 Trends in K/L and W/R in construction

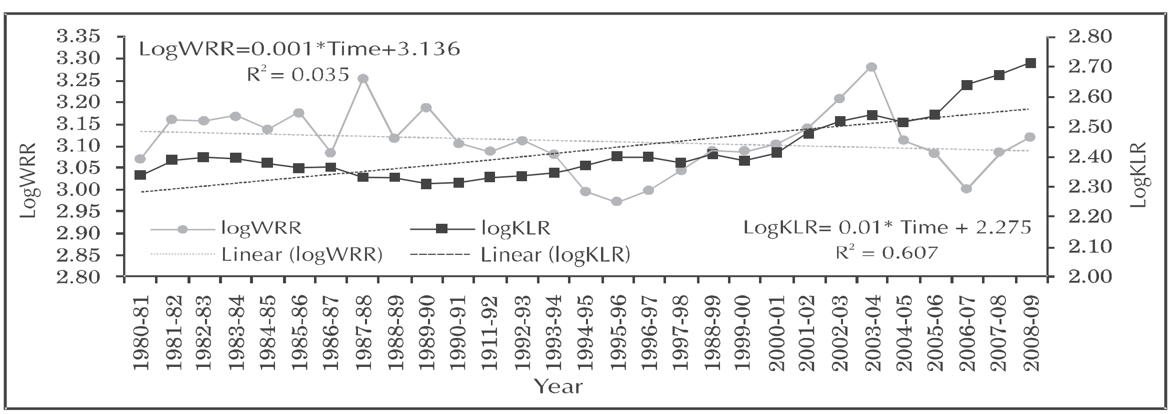


Figure 5 Trends in K/L and W/R in hotels and restaurants

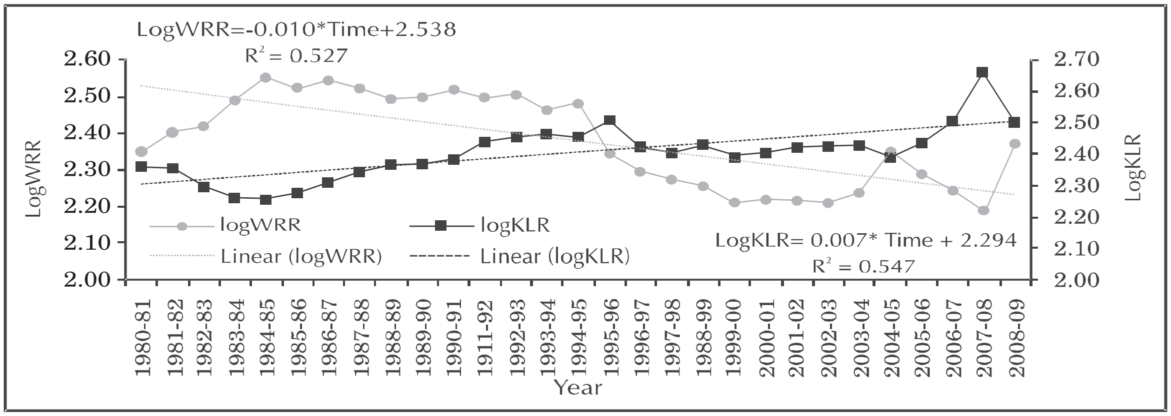


Figure 6 Trends in K/L and W/R in railways, transport by other means, and storage

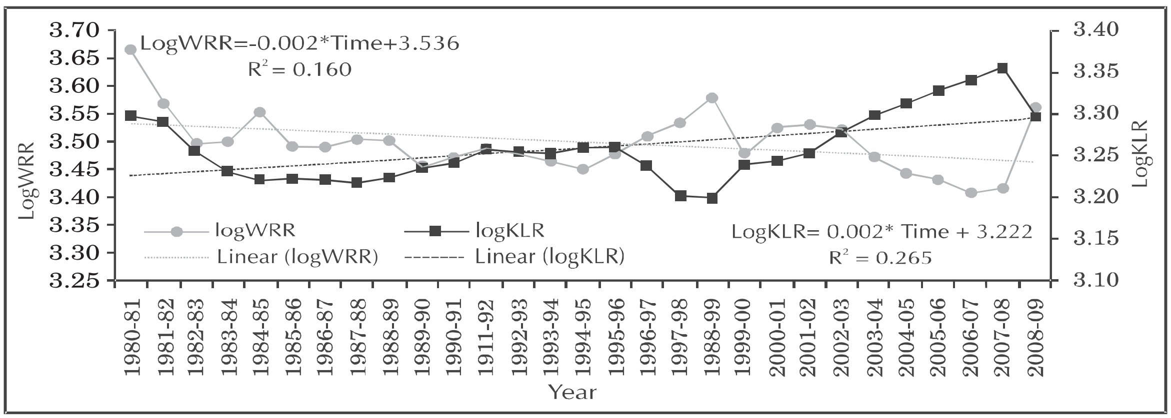


Figure 7 Trends in K/L and W/R in post and communication

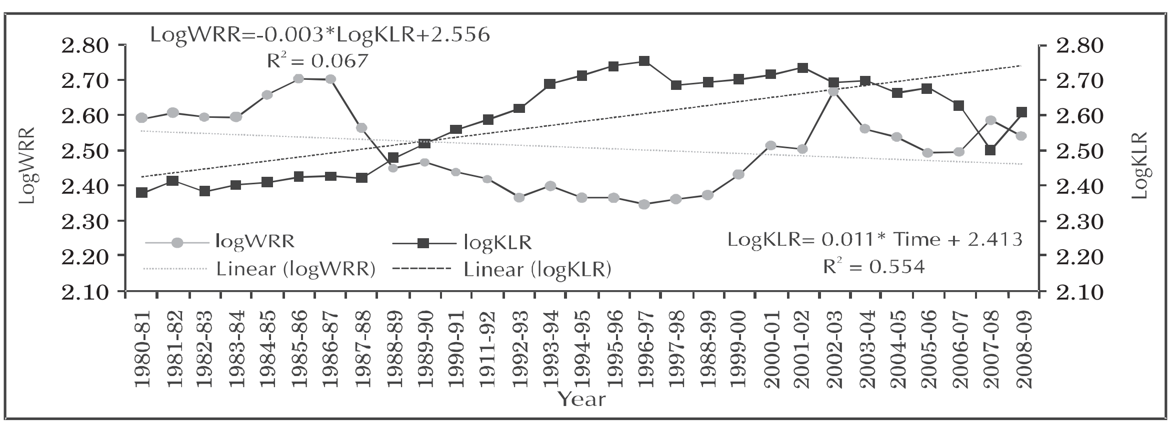
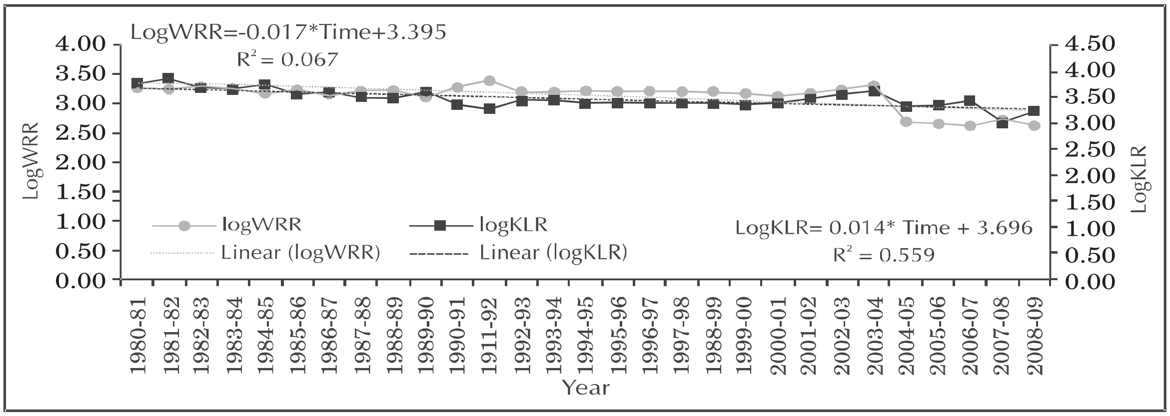


Figure 8 Trends in K/L and W/R in real estate, ownership of dwellings and business services



5.2 Econometric Results

Estimates of elasticity of substitution between capital and labour in major sectors of the Indian economy are presented in Table 4.

Table 4 Estimates of elasticity of substitution (estimated value of σ)

Sector	SMAC Functions	Non-linear least squares, ν =1	Kmenta approximation ν =1	Kmenta approximation, ν unrestricted
Agriculture, including livestock	0.63 (0.03; 0.000)	1.14 (0.03; 0.00)	1.36 (0.36; 0.02)	1.33 (0.07; 0.00)
Forestry and logging	0.91 (0.03; 0.000)	0.67 (0.14; 0.00)	1.93 (1.45; 0.25)	1.97 (0.05; 0.00)
Fishing	0.87 (0.01; 0.000)	0.34 (0.04; 0.00)	-174.15 (12474.9; 1.00)	(1.37; 0.06)
Mining and quarrying	0.93 (0.06; 0.000)	0.36 (0.003; 0.00)	0.93 (0.64; 0.22)	1.59 (0.05; 0.00)
Manufacturing	0.96 (0.10; 0.000)	0.71 (0.34; 0.05)	1.38 (1.61; 0.44)	1.35 (0.05; 0.00)
Electricity, gas, and water supply	0.70 (0.07; 0.000)	1.22 (0.01; 0.00)	1.40 (0.33; 0.01)	1.35 (0.05; 0.00)
Construction	0.56 (0.11; 0.000)	0.28 (1.63; 0.86)	1.96 (1.39; 0.23)	1.99 (0.27; 0.00)
Trade	0.94 (0.06; 0.000)	0.50 (74.10; 1.00)	1.24 (6.42; 0.86)	1.51 (0.03; 0.00)

Table 4 Estimates of elasticity of substitution (estimated value of σ) (cont.)

Sector	SMAC Functions	Non-linear least squares, ν =1	Kmenta approximation ν =1	Kmenta approximation, ν unrestricted
Hotels and Restaurants	0.10 (0.10; 0.346)	1.27 (0.09; 0.00)	1.57 (1.55; 0.37)	1.68 (0.03; 0.00)
Railways, transport by other means and storage	0.31 (0.10; 0.001)	0.35 (11.62; 0.98)	1.51 (3.52; 0.69)	1.44 (0.01; 0.00)
Post and communication	0.73 (0.05; 0.000)	1.34 (0.26; 0.00)	1.57 (0.59; 0.06)	1.57 (0.03; 0.00)
Banking and insurance	1.30 (0.07; 0.000)	1.74 (3.93; 0.66)	1.46 (0.27; 0.01)	1.41 (0.10; 0.00)
Real estate, ownership of dwellings and business services	0.72 (0.07; 0.000)	0.36 (0.05; 0.00)	1.43 (0.25; 0.00)	1.47 (0.06; 0.00)
Public administration and defence	0.88 (0.02; 0.000)	1.21 (0.02; 0.00)	1.35 (0.15; 0.00)	1.35 (0.00; 0.00)
Other services	1.07 (0.02; 0.000)	1.49 (0.998; 0.011)	1.57 (0.12; 0.00)	1.49 (0.11; 0.00)
All sectors	0.56 (0.14; 0.000)	1.58 (2.76; 0.572)	1.27 (0.12; 10.459)	1.36 (6.10; 0.224)

Note: SMAC function: SURE has been performed for equations (2) and (3). The figures in parentheses in are Std. Err. and P>|t|).

The first set of estimates is based on the SMAC functions (equations 2 and 3). The second set of estimates has been obtained by direct estimation of the CES production function by non-linear least squares. The third set of estimates is based on Kmenta approximation to the CES function.

It is seen from Table 4 that the different methods of estimation of the elasticity of substitution yields quite dissimilar results. The estimates of the elasticity obtained by the Kmenta approximation to the CES function are almost uniformly above 1, which is probably caused by a bias in parameter estimates associated with this method (mentioned above). Accordingly, it seems, greater reliance should be placed on the estimates obtained by the direct estimation of the CES function by non-linear least square method and the estimation of SMAC equations by the SURE method. The estimates obtained by the direct estimation of the CES function by non-linear least square method seem to be preferable to those obtained by the estimation of SMAC equations by SURE method in the case of agriculture, fishing, and forestry sectors because certain approximations had to be made to derive factor incomes in these sectors. The elasticity estimates obtained by the direct estimation of the CES function may have a slight edge over the estimates based on the SMAC function also for other sectors because direct estimation of the CES function does not require the assumption of competitive markets, perfect flexibility in the adjustment of input use, and profit maximisation.

Considering the estimates presented in Table 4, the following inferences may be drawn.

- The elasticity of substitution is less than 1 in (1) forestry and logging, (2) fishing, (3) construction, (4) railways and other transport, and (5) real estate, ownership of dwellings and business services.

- The elasticity of substitution seems to be about 1 or more than 1 in (1) agriculture including livestock, (2) electricity, gas and water supply, (3) trade, (4) banking and insurance, (5) public administration and defence, and (6) 'other services'.

- For manufacturing, the estimate based on the SMAC function is close to 1 while that based on direct estimation of the CES function by non-linear least squares in significantly below 1. The latter seems more probable. The same applies to mining and quarrying. In this case, too, the elasticity of substitution seems to be less than 1.

- In post and communication, the estimate based on the SMAC function is less than 1 while that based on direct estimation of the CES function by non-linear least squares is above 1, though the difference is not statistically significant (even the estimated coefficient is not statistically significant). The estimates based on the Kmenta approximation are above 1 but the gap is not statistically significant. Considering all the estimates and diversity among them, it seems that the elasticity of substitution in post and communication should be taken as about 1 or slightly higher.

- In the case of hotels and restaurants, the estimate of elasticity of substitution based on the SMAC function is rather low at 0.1, compared to which the estimates based on the direct estimation of the CES function are much higher (1.27 to 1.68). Given the big difference between the two estimates, it would be useful to consider the estimate of elasticity of substitution between capital and labour obtained for the hotel and restaurants sector in other studies. Sector-wise estimates of elasticity of substitution in Rhodesia presented by Muzando (1978) indicate that the elasticity of substitution is relatively high in distribution, hotels and restaurants than in other sectors of the economy (1.089 in distribution, hotels and restaurants as against 0.899 in agriculture and forestry, and 0.586 in manufacturing). By contrast, the estimates of short-term elasticity of substitution made for New Zealand by Tipper (2011) indicate that the elasticity of substitution in hotel and restaurants (0.13) is lower than that in construction (0.25), electricity (0.5), retail trade (0.18), finance and insurance (0.22), and most manufacturing industries. Since the estimates of substitution elasticity for Rhodesia and New Zealand obtained in the studies of Muzando and Tipper respectively show an opposite pattern, it is unclear whether the elasticity of substitution in hotel and restaurants in India should be taken as 0.1, as given by the estimate based on the SMAC function, or as 1 or more than 1, as the estimates based on direct estimation of the CES function indicate.

- Elasticity of substitution between capital and labour in 'all sectors' has been obtained as 0.56 based on the SMAC function. The estimates based on other alternative methods are higher than 1.

The estimates presented in Table 4 above indicate that the elasticity of substitution is less than 1 in (1) forestry and logging, (2) fishing, (3) construction, (4) railways and other transport, and (5) real estate, ownership of dwellings and business services. This assessment is by and large corroborated by the estimates of elasticity of substitution presented in Table 5. The estimates of the elasticity of substitution for manufacturing and mining and quarrying presented in Table 5 clearly indicate a less than unitary elasticity of substitution. This is in agreement with the inference drawn about the elasticity of substitution in manufacturing based on the estimates shown in Table 4.

One common feature of the estimates of elasticity of substitution presented in Table 4 is that these were based on the assumption of Hicks-neutral technical change. Three alternative sets of estimates are presented in Table 5, which allow for non-neutral technical change. The first set of estimates have been obtained by estimating equations (6) and (7) jointly by applying the SURE technique. This is different from the estimates presented in Table 4 in that non-neutral technical change is permitted and therefore the coefficients of time variable in the two equations are not constrained to the same value. The other two sets of estimates presented in Table 5 are obtained by estimating equations (6) and (7) separately by the ARDL model. This introduces dynamics in the model. Also, it permits testing of co-integration by the ARDL approach. The table presents F-statistics for testing for the existence of a long-term relationship between the variables, and whether or not it exceeds the critical value is also shown.

Table 5 Estimates of elasticity of substitution, alternative set of estimates

Sector	SMAC Functions allowing for non-neutral technical change	Eq. (6) by ARDL model		Eq(7) by ARDL model	
	Elasticity of Substitution (Std. Err.)	Elasticity of Substitution (Std. Err.)	Max. lag taken in the Model [F-stat for existence of long-run relationship]	Elasticity of Substitution (Std. Err.)	Max. lag taken in the Model [F-state for existence of long-run relationship]
Agriculture, including livestock	0.80 (0.04)	0.28 (0.31)	1 [8.67]@$	0.09 (0.34)	1[5.95]
Forestry and logging	0.98 (0.01)	—	—	0.55(0.13)	3[7.07]@@$
Fishing	0.86 (0.03)	0.67(0.23)	2[5.18]$	Not estimated	
Mining and quarrying	0.43 (0.09)	0.60(0.23)	2[7.75]@@$	Not estimated	
Manufacturing	0.73 (0.04)	0.48(0.13)	4[10.21]@$	0.29(0.12)	2[6.59]#$
Electricity, gas and water supply	0.17 (0.02)	—	—	0.21(0.03)	2[9.69]@$
Construction	0.73 (0.08)	0.69(0.23)	2[8.47]@$	1.42(1.10)	1[1.52]
Trade	0.94(0.05)	0.76(0.45)	4[1.16]$$	0.83(0.18)	4[3.43]$
Hotels and restaurants	0.60(0.06)	—	—	0.94(0.16)	2[6.17]@@$
Railways, transport by other means, and storage	0.43(0.09)	1.55(1.34)	1[3.60]	0.11(1.80)	1[0.68]
Post and communication	0.70(0.04)	0.27(0.08)	2[8.61]@$	1.24(3.78)	1[0.04]
Banking and insurance	1.04 (0.02)	0.56(0.27)	2[4.32]$	0.60(0.70)	2[1.18]
Real estate, ownership of dwellings, and business services	0.61(0.08)	2.00(2.94)	3[4.70]	0.22(0.64)	1[2.21]$
Public administration and defence	0.80(0.03)	0.96(0.13)	2[1.24]	Not estimated	
Other services	0.98(0.01)	0.97(0.04)	2[5.70]$	1.04(0.03)	2[8.43]@$
All sectors	0.56 (0.14)	0.94 (0.94)	4[3.67]…	1.10 (1.28)	1[0.60]…

Note: SMAC function: Equations (6) and (7) jointly estimated by SURE method.
@ F-statistics exceeds upper bound at 95% level of confidence.
@@ F-statistics exceeds upper bound at 90% level of confidence.
# F-statistics between upper and lower bound at 90% level of confidence.
$ ECM term in the error correction model is negative and statistically significant.
$$ ECM term in the error correction model is negative but not statistically significant.
— results unsatisfactory, hence not reported.

The elasticity estimates presented in Table 4 above indicated that the elasticity of substitution is about 1 or more than 1 in (1) agriculture including livestock, (2) electricity, gas and water supply, (3) trade, (4) banking and insurance, (5) public administration and defence, and (6) 'other services'. For banking and insurance, public administration and defence, and 'other services', the estimates shown in Table 5 are by and large supportive of the inference drawn from Table 4. But, in the other three cases, there is some degree of disagreement between the estimates presented in Table 4 and those presented in Table 5. For agriculture, it seems better to base inferences on direct estimation of the CES function. Hence, for this sector, the elasticity of substitution may be taken as 1 or higher than 1. As regards trade, the estimates presented in Table 4 indicate that the elasticity of substitution is about 1 or more than 1. The estimates shown in Table 5 are less than 1, but the gap is not statistically significant. Thus, it seems reasonable to infer that the elasticity of substitution in trade is about 1 or slightly higher than 1. For electricity, gas and water supply, the estimates of elasticity of substitution obtained by direct estimation of the CES function indicate that the elasticity of substitution is more than 1. On the other hand, the estimates based on the SMAC functions in both Tables 4 and 5 indicate that the elasticity of substitution is well below 1. In the estimates of elasticity of substitution obtained by Tipper (2011) for New Zealand, the elasticity of substitution in electricity, gas and water supply is higher than the elasticity of substitution in other sectors of the economy. Accordingly, the estimates obtained by direct estimation of the CES function may be taken as the basis for assessing the elasticity of substitution in electricity, gas and water supply sector in India. The elasticity of substitution in this sector thus appears to be about 1 or slightly more than 1.

For post and communications, the assessment based on the estimates presented in Table 4 was that the elasticity of substitution is about 1 or more than 1. This inference is not supported by the estimates given in Table 5. The estimate obtained by the joint estimation of the SMAC function with non-neutral technical change is less than 1 and the gap is statistically significant. The estimate obtained by applying the ARDL model to equation (6) is quite low at 0.27. This is significantly below 1. The F-test for this model clearly shows the existence of a long-term relationship between labour productivity and real product wage rate. Considering all these, it seems reasonable to conclude that the elasticity of substitution in this sector is less than 1.

For hotels and restaurants, no clear inference could be drawn from Table 4 about the level of substitution elasticity in this sector. The estimates presented in Table 5 suggest that the substitution elasticity is about 1 or less than 1. This inference is broadly consistent also with the estimates presented in Table 4. Thus, considering the estimates presented in Tables 4 and 5 and the elasticity estimates obtained for New Zealand by Tipper (2011), it seems reasonable to infer that elasticity of substitution in Hotels and restaurants is about 1 or less than 1, more likely the latter.

The above discussion has brought out that the elasticity of substitution between capital and labour is less than 1 in most sectors of the Indian economy. This suggests that at the aggregate economy level too, the elasticity of substitution is probably below 1, which is consistent with the estimates of elasticity of substitution in the Indian economy obtained in the studies of Mallick (2007) and Wang (2012).

Next, it would be interesting to compare the manufacturing and the services sectors in India. The estimates presented above indicate that the elasticity of substitution is less than 1 in manufacturing. In several services sectors, however, the elasticity of substitution was found to be more than 1. This gives the impression that the elasticity of substitution for the services sector as a whole might be greater than that for manufacturing. To verify this, the models described above were estimated for the aggregate services sector.[5] The time series on output, input, and factor price variables were constructed for the aggregate services sector by combining the time series for individual sectors comprising the services sector. The estimated elasticity of substitution is shown in Table 6 along with comparable estimates for manufacturing.

Table 6 Estimates of elasticity of substitution in manufacturing and service sectors

Sector	SMAC Functions		Non-linear least squares	Kmenta approximation		Eq. (6) by ARDL, long term coefficient	Eq. (7) by ARDL, long term coefficient
	Without restriction on coefficients of t	With restriction on coefficients of t	With $\nu = 1$	Equation 4, ν unrestricted	Equation 5, $\nu = 1$		
Manufacturing	0.73 (0.04)	0.96 (0.10)	0.71 (0.34)	1.35 (0.05)	1.38 (1.61)	0.48 (0.13)	0.29 (0.12)
Services	0.97 (0.02)	1.00 (0.03)	0.76 (98.2)	1.33 (0.03)	1.33 (0.18)	0.83 (0.44)	2.94 (1.11)

Note: Figures in parentheses are standard errors.

[5] Services sector includes trade, hotels and restaurants, transport, post and communication, banking and insurance, real estate (including ownership of dwellings and business services), public administration and defence, and other services.

It is seen that estimated elasticity of substitution for the services sector is more than that for manufacturing when the SMAC model is applied without restriction on coefficients of time variable (i.e. allowing for non-neutral technical change) or when the ARDL model is applied to the SMAC functions. But, in some other cases, the elasticity of substitution is found to be slightly lower for the services sector than the manufacturing sector. In the estimate based on non-linear least squares, the estimated elasticity of substitution for the services sector is slightly higher than that for manufacturing, but the estimated elasticity for the services sector is not statistically significant. Overall, the estimates suggest that the elasticity of substitution in the services sector is higher than that in the manufacturing sector. Table 7 shows the rates of labour and capital augmenting technical change in the manufacturing and services sectors.

Table 7 Estimates of elasticity in manufacturing and service sectors, SMAC model

Sectors	Estimate of elasticity of substitution, without restriction on coefficients of t	Rate of labour augmenting technical change (λ_L)	Rate of capital augmenting technical augmenting technical (λ_K)
Manufacturing	0.73 (0.04)	0.04(0.01)	-0.02(0.00)
Services	0.97(0.02)	0.06(0.04)	-0.02(0.03)

Note: Figures in parentheses are standard errors.

These estimates have been derived from joint estimation of the SMAC function with SURE method after allowing for non-neutral technical change. The results for manufacturing clearly indicate that there was significant labour-saving technical change. In the case of services, the estimated rates of factor augmentation are statistically insignificant. Yet, the estimates give an impression that there was significant labour-saving technical change also in the services sector. In terms of the numerical value of the coefficients, the labour-saving bias in the services sector is found to be greater than that in the manufacturing sector.

Table 8 shows that elasticities of substitution in market service sectors and in non-market service sectors are not much different from each other. It infers that market forces do not have significant impact on the elasticity of substitution between capital and labor in service sectors.

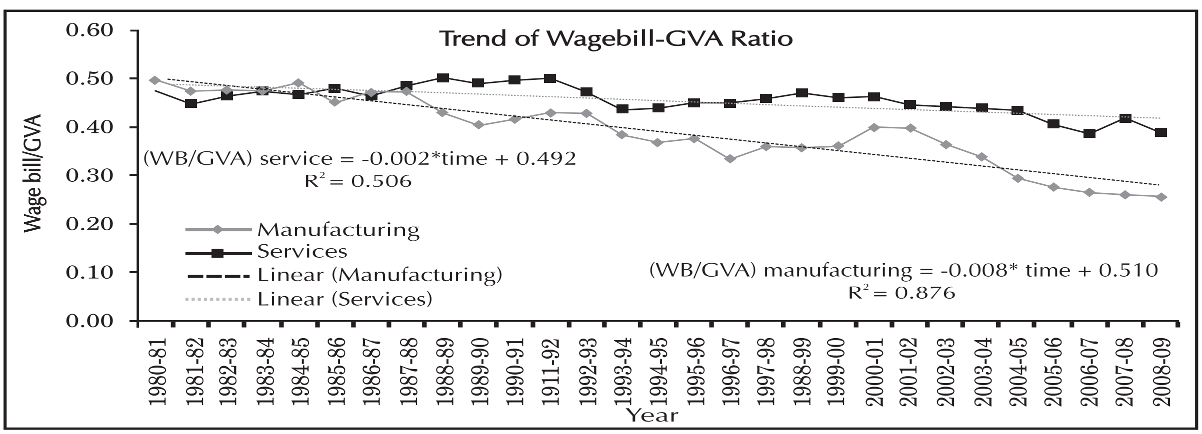
Table 8 Estimates of elasticity of substitution in market and non-market service sectors

Sector	SMAC Functions		Non-linear least squares	Kmenta approximation		Eq. (6) by ARDL, long term coefficient	Eq. (7) by ARDL, long term coefficient
	Without restriction on coefficients of t	With restriction on coefficients of t	With ν =1	Equation 4, ν unrestricted	Equation 5, ν =1		
Market services[6]	0.98 (0.01)	1.04 (0.04)	0.42 (0.87)	1.39 (10.23)	1.35 (0.18)	0.70 (0.24)	1.72 (0.29)
Non-market services[7]	0.80 (0.03)	0.88 (0.02)	1.57 (1.13)	1.35 (0.26)	1.35 (0.15)	Not estimated	Not estimated

Note: Figures in parentheses are standard errors.

The finding of a less than unitary elasticity of substitution implies that as the capital–labour ratio goes up, the income share of labour in value added should increase. This, however, did not happen in India's manufacturing and services sectors as may be seen from Figure 9.

Figure 9 Trends in wage bill–GVA ratio of manufacturing and services sectors



Note: WB=wage bill.

[6] Marketed service sectors include construction, trade, hotels and restaurants, railways, transport by other means and storage, post and communication, banking and insurance, real estate, ownership of dwellings and business services, and other services.

[7] Non-marketed services sector represents public administration and defence.

The explanation may be sought in labour-saving technical change. It may be noticed from Table 7 that the elasticity of substitution is higher and the labour-saving bias in technical change is greater in the services sector than in the manufacturing sector. One would accordingly expect the fall in the income of share of labour to be greater in the services sector. But the opposite has happened, as may be seen from Figure 9. It seems certain other factors have caused the income share of labour in manufacturing to decline faster than in services, possibly because the gap between the marginal product of labour and the wage rate has widened in the manufacturing sector over time (caused perhaps by declining bargaining strength of industrial labour). Indeed, the analysis undertaken by Virmani and Hashim (2009) for the organised manufacturing sector reveals that there was almost no gap between the marginal product of labour and the wage rate between 1980 and 1991. But the wage rate between 1992 and 2001 was about 17 per cent lower than the marginal productivity of labour. This increase in the gap between wage rate and marginal product of labour may explain the significant fall in the income share in labour in value added in the manufacturing sector.

6 CONCLUDING REMARKS

In this paper, the elasticities of substitution between capital and labour inputs are estimated for the 15 major sectors that together comprise the entire Indian economy. The estimation is based on a CES production function, using annual time series data for the period between 1980–81 and 2008–09. Seven sets of estimates of the elasticity of substitution were made using alternate specifications of the model and econometric techniques of estimation of parameters. The results indicate that the elasticity of substitution is less than 1 in a majority of sectors of the Indian economy. A comparison of the estimates obtained for the manufacturing and the services sectors indicated that the elasticity of substitution in manufacturing is less than that in the services sector. Also, significant labour-saving technical change was found in both manufacturing and services sectors during the period under study; the bias being stronger in services than in manufacturing.

There was a significant downward trend in labour income share in value added in the manufacturing sector between 1980 and 2008 and to a lesser extent in the services sector also. The observed downward trend in income share of labour in the manufacturing and services sector seems to be attributable, at least partly, to labour-saving technical change. In the case of manufacturing, other factors have possibly created or widened the gap between wage rate and marginal product of labour, because of which the fall in the income share of labour was much faster in manufacturing than in services. This is a matter to be investigated in future research.

That the elasticity of substitution is lower in manufacturing than in services implies that diminishing returns to capital may pose a bigger challenge to the sustenance of growth in manufacturing than in services. This could be overcome to some extent by labour-saving technical change. But, even in terms of labour-saving bias of technical change, manufacturing ranks lower than services. One question that poses itself here is: does the relatively superior growth of services than manufacturing in India have something to do with the relatively higher elasticity of substitution between capital and labour, and relatively stronger labour-saving bias of technical change? This is another aspect that needs further investigation.

REFERENCES

Alvarez-Cuadrao, Francisco and Ngo Van Long. 2011. 'Capital-Labour Substitution, Structural Change and Growth,' CIRANO Working Papers 2011s-68, CIRANO.

Chadha, Rajesh, Sanjib Pohit and P. L. Bina (1995), 'Capital-Labor Substitution in Indian Industries', paper presented at *The Thirty-First Annual Conference of the Indian Econometric Society,* National Institute of Bank Management, Pune,12-14 May.

de la Grandville, Oliver (1989), 'In Quest of the Slutsky Diamond', *American Economic Review* 79 (June), 468-481.

Dissanayake, Jagath and Nicholas Sim. 2010. 'Across Country Empirical Investigation of the Aggregate Production Function using Panel Quantile Regression.' Proceedings of the 39th Australian Conference of Economists (ACE 10).

Duffy, J. and C. Papageorgiou. 2000. 'A Cross-Country Empirical Investigation of the Aggregate Production Function Specification.' *Journal of Economic Growth* 5: 87-120.

Fragiadakis, Kostas, Leonidas Paroussos, Nikos Kouvaritakis and Pantelis Capros. 2012. 'A Multi – Country Econometric Estimation of the Constant Elasticity of Substitution', paper presented at the Final WIOD Conference: Causes and Consequences of Globalization, Groningen, The Netherlands, 24-26 April 2012.

Ghate, Chetan and Stephen Wright. 2012. 'The 'V Factor': Distribution, Timing and Correlates of the Great Indian Growth Turnaround.' *Journal of Development Economics* 99(1): 58–67.

Goldar, Bishwanath. 2013 (forthcoming). 'Wages and Wage Share in India in the Post-Reform Period.' *Indian Journal of Labour Economics*.

Goldar, Bishwanath, Basanta K. Pradhan and Akhilesh K. Sharma. 2013. 'Elasticity of Substitution between Capital and Labour Inputs in Manufacturing Industries of the Indian Economy', *Journal of Industrial Statistics*2 (2): 169–94.

Gollin, D. 2002. 'Getting Income Shares Right.' *Journal of Political Economy* 110(2): 458–74.

Mallick, Debdulal. 2007. 'The Role of the Elasticity of Substitution in Economic Growth: A Cross-Country Test of the de La Grandville Hypothesis,' Economics series 2007-04, Deakin University, Faculty of Business and Law, School of Accounting, Economics and Finance.

Muzondo T.R. 1978. 'Sectoral Elasticities of Substitution Between Capital and Labour: Rhodesia, 1954-1975.' *South African Journal of Economics* 46(1, March): 22–31.

Narasimham, G.V.L and M.Z. Fabrycy. 1974. 'Relative Efficiencies of Organised Industries in India, 1949-58.' *Journal of Development Studies* 10(2, January): 230–41.

Pradhan, Basanta K., M.R. Saluja and S.K. Singh. 2006. *Social Accounting Matrix for India: Concepts, Construction and Applications*. New Delhi: Sage Publications.

Shankar, U. 1970. 'Elasticities of Substitution and Returns to Scale in Indian Manufacturing Industries.' *International Economic Review* 2 (3 October): 399–411.

Thursby, J.G. and C.A.K. Lovell. 1978. 'An Investigation of the Kmenta Approximation to the CES Function.' *International Economic Review* 19 (2, June): 363–77.

Tipper, Adam. 2011. 'One for all? The Capital-Labour Substitution Elasticity in New Zealand', paper prepared for the 52nd New Zealand Association of Economists conference, Wellington, New Zealand, June 2011.

Varma, Rubina. 2008. 'The Service Sector Revolution in India', Research Paper no. 2008/72, UNU-WIDER.

Virmani, Arvind and Danish A. Hashim. 2009. 'Factor Employment, Sources and Sustainability of Output Growth: Analysis of Indian Manufacturing.' Working paper no. 3/2009-DEA, Ministry of Finance, Government of India.

Wang, Yong. 2012. 'Estimating CES Aggregate Production Functions of China and India,' Department of Economics and Finance, City University of Hong Kong.

Whalley, John and Chunbing Xing. 2012. 'The Sustainability of Chinese Growth and the Aggregate Factor Substitution Elasticity.' CESIFO Working paper no. 3736, February.

APPENDIX

Dickey-Fuller and Augmented Dickey-Fuller tests

Table A1 Dickey-Fuller and Augmented Dickey-Fuller Tests (agriculture sector, including livestock)

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.04	1.41	-0.38	0.06
		1.43	1.76	-0.52	0.12
	First difference	-6.50*	-5.82*	-8.85*	-8.16*
		-3.03*	-2.57*	-4.04*	-3.72*
An intercept but not a trend	Level	-1.30	-0.85	-2.31	-1.78
		-1.31	-0.81	-1.57	-0.98
	First difference	-6.80*	-6.34*	-8.72*	-8.00*
		-3.24*	-2.87	-4.00*	-3.65*
An intercept and a linear trend	Level	-1.39	-1.66	-2.28	-1.69
		-0.27	-1.06	-0.78	-0.65
	First difference	-7.09*	-6.31*	-9.18*	-8.94*
		-3.49	-2.88	-4.43*	-4.48*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A2 Dickey-Fuller and Augmented Dickey-Fuller tests: forestry and logging sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	-0.97	-0.78	- 7.72*	-1.17
		-1.17	0.82	-6.02*	0.92
	First difference	-6.26*	-5.58*	-3.17*	-4.94*
		-3.58*	-4.91*	-2.13*	-2.47*
An intercept but not a trend	Level	-3.11*	-3.33*	-5.79*	-3.32
		-2.85	-3.27*	-5.35*	-3.67*
	First difference	-6.28*	-5.51*	-3.69*	-5.69*
		-3.60*	-4.95*	-2.38	-2.90
An intercept and a linear trend	Level	-3.21	-3.29	-3.16	-3.20
		-2.85	-3.27	-3.16	-2.95
	First difference	-6.20*	-5.44*	-5.25*	-6.37*
		-3.57	-4.93*	-4.02*	-3.45

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A3 Dickey-Fuller and Augmented Dickey-Fuller tests: fishing sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	2.31 2.47	2.75 2.23	-0.02 -0.94	2.82 -0.02
	First difference	-4.73* -2.59*	-3.74* -2.16*	-1.69 -1.35	-1.74 -1.78
	Second Difference	-9.28* -6.42*	-8.72* -5.59*	-6.83* -5.28*	-5.12* -4.58*
An intercept but not a trend	Level	-0.29 -0.23	-0.17 -0.19	2.14 0.10	1.36 -0.51
	First difference	-6.30* -3.97*	-5.16* -3.35*	-2.24 -1.88	-2.09 -2.18
	Second Difference	-9.09* -6.28*	-8.53* -5.47*	-6.80* -5.32*	-5.05* -4.54*
An intercept and a linear trend	Level	-2.19 -1.94	-2.17 -2.39	-2.59 -2.40	-2.04 -2.36
	First difference	-6.22* -3.93*	-5.06* -3.26	-2.60 -2.22	-2.12 -2.33
	Second Difference	-8.79* -6.07*	-8.23* -5.26*	-7.18* -5.78*	-5.17* -4.74*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A4 Dickey-Fuller and Augmented Dickey-Fuller tests: mining and quarrying sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.82 1.91	1.26 1.27	1.23 0.65	0.61 0.68
	First difference	-6.05* -3.70*	-5.43* -3.66*	-2.83* -1.85	-3.97* -4.24*
An intercept but not a trend	Level	-1.71 -1.80	-1.15 -1.08	-2.36 -2.92	-1.82 -2.66
	First difference	-6.65* -4.22*	-5.78* -3.99*	-2.87 -1.90	-4.00* -4.20*
An intercept and a linear trend	Level	-2.45 -2.25	-1.44 -1.38	-2.36 -2.87	-1.83 -2.83
	First difference	-6.64* -4.33*	-5.83* -4.03*	-2.72 -1.71	-3.96* -4.13*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A5 Dickey-Fuller and Augmented Dickey-Fuller tests: manufacturing sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.84	0.69	1.59	-0.08
		1.63	0.67	1.29	-0.08
	First difference	-4.21*	-4.82*	-4.19*	-4.56*
		-3.56*	-4.26*	-3.65*	-3.80*
An intercept but not a trend	Level	-0.86	-2.17	-0.89	-2.70
		-0.86	-2.15	-1.06	-3.58*
	First difference	-4.65*	-4.81*	-4.40*	-4.47*
		-4.24*	-4.29*	-4.03*	-3.73*
An intercept and a linear trend	Level	-2.52	-1.94	-2.85	-2.74
		-3.01	-1.95	-4.23*	-3.67
	First difference	-4.55*	-4.87*	-4.33*	-4.37*
		-4.15*	-4.70*	-3.98*	-3.64*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A6 Dickey-Fuller and Augmented Dickey-Fuller tests: electricity, gas, and water supply sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	2.68	1.84	-2.30*	-0.29
		2.08	1.57	-1.85	-0.16
	First difference	-3.55*	-4.04*	-3.80*	-3.17*
		-1.81	-2.97*	-3.06*	-2.18*
An intercept but not a trend	Level	-0.01	0.57	-1.16	-1.05
		-0.09	0.43	-1.13	-1.37
	First difference	-4.45*	-4.44*	-4.46*	-3.11*
		-2.49	-3.45*	-3.91*	-2.13
An intercept and a linear trend	Level	-1.82	-1.51	-0.82	0.47
		-1.94	-1.53	-1.18	-0.28
	First difference	-4.36*	-4.77*	-4.69*	-3.75*
		-2.43	-3.90*	-4.28*	-2.74

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A7 Dickey-Fuller and Augmented Dickey-Fuller tests: construction sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	-0.52 -0.65	-1.33 -1.64	-1.51 -1.06	-0.07 0.16
	First difference	-7.37* -3.85*	-6.75* -3.09*	-3.47* -3.01*	-7.62* -3.67*
An intercept but not a trend	Level	-3.37* -3.00	-2.94 -2.48	2.11 1.18	-2.85 -2.11
	First difference	-7.18* -3.73*	-6.81* -3.04*	-3.81* -3.45*	-7.47* -3.60*
An intercept and a linear trend	Level	-4.23* -3.80*	-3.06 -2.59	0.43 -0.32	-2.79 -2.07
	First difference	-7.10* -3.59*	-6.66* -2.97	-5.50* -5.33*	-7.35* -3.45

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A8 Dickey-Fuller and Augmented Dickey-Fuller tests: trade sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	2.25 2.04	3.30 2.15	-0.78 -1.00	-1.74 -1.61
	First difference	-3.23* -3.30*	-2.86* -3.07*	-3.20* -2.43*	-4.26* -3.80*
An intercept but not a trend	Level	1.24 1.25	0.24 -0.14	-0.85 -0.99	-0.29 -0.30
	First difference	-3.86* -4.54*	-3.59* -4.30*	-3.46* -2.69	-4.66* -4.49*
An intercept and a linear trend	Level	-1.39 -1.32	-1.80 -2.19	-1.16 -2.04	-2.51 -2.80
	First difference	-4.41* -5.94*	-3.59 -4.43*	-3.43 -2.67	-4.61* -4.44*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A9 Dickey-Fuller and Augmented Dickey-Fuller tests: hotels and restaurants sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.01 1.71	1.80 1.91	-1.53 -1.45	-1.10 -1.10
	First difference	-6.07* -3.63*	-4.36* -3.64*	-4.09* -2.31*	-4.63* -2.68*
An intercept but not a trend	Level	-0.77 0.27	-0.02 0.21	-0.50 -0.56	-0.61 -0.53
	First difference	-6.69* -4.27*	-4.84* -4.43*	-4.12* -2.36	-4.73* -2.80
An intercept and a linear trend	Level	-5.16* -4.14*	-2.52 -2.31	-1.37 -1.38	-2.46 -2.44
	First difference	-6.70* -4.40*	-4.87* -4.57*	-4.13* -2.39	-4.58* -2.55

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A10 Dickey-Fuller and Augmented Dickey-Fuller tests: railways, transport by other means and storage sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.30 0.85	1.84 1.63	-2.91* -1.18	-0.86 -0.82
	First difference	-2.92* -2.10*	-4.96* -4.28*	-2.65* -1.96*	-4.19* -3.20*
An intercept but not a trend	Level	-0.96 -1.13	-0.59 -0.67	-3.68* -2.54	-2.06 -2.02
	First difference	-3.08* -2.24	-6.05* -5.67*	-2.75 -1.87	-4.10* -3.09*
An intercept and a linear trend	Level	-2.27 -2.74	-3.01 -3.84*	-0.21 -0.50	-2.30 -2.35
	First difference	-2.81 -1.92	-6.08* -5.66*	-3.92* -2.93	-4.12* -3.19

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A11 Dickey-Fuller and Augmented Dickey-Fuller tests: communication sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	2.93 2.46	2.49 1.49	-1.74 -1.10	-2.17* -1.82
	First difference	-3.00* -2.58*	-2.68* -1.53	-2.24* -1.32	-3.47* -2.70*
An intercept but not a trend	Level	0.79 0.75	1.53 0.72	2.35 0.71	0.88 0.79
	First difference	-4.14* -4.19*	-3.17* -1.97	-2.66 -1.72	-4.30* -3.69*
An intercept and a linear trend	Level	-2.71 -2.69	-1.05 -1.20	-0.64 -0.85	-2.41 -2.40
	First difference	-4.30* -4.69*	-3.84* -2.54	-3.91* -2.80	-4.60* -4.25*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A12 Dickey-Fuller and Augmented Dickey-Fuller tests: banking and insurance sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	4.05 3.76	3.10 2.75	-0.39 -0.48	-1.11 -1.12
	First difference	-3.74* -1.82	-3.87* -2.43*	-3.21* -1.95*	-5.11* -2.85*
An intercept but not a trend	Level	0.06 0.16	-0.54 -0.51	-0.86 -1.25	-0.87 -0.90
	First difference	-5.77* -3.66*	-4.98* -3.56*	-3.15* -1.90	-5.06* -2.83
An intercept and a linear trend	Level	-2.32 -2.06	-1.99 -2.05	0.10 -0.60	-0.64 -0.60
	First difference	-5.72* -3.59*	-4.87* -3.48	-3.47 -2.19	-5.43* -3.12

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.
*exceeds published critical value

Table A13 Dickey-Fuller and Augmented Dickey-Fuller tests: real estate, ownership of dwellings, and business services sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	-0.57	-0.65	-4.18*	-1.10
		-0.85	-0.66	-1.22	-1.30
	First difference	-7.83*	-5.37*	-2.01*	-5.93*
		-6.78*	-3.68*	-1.68	-5.93*
An intercept but not a trend	Level	-3.93*	-0.90	-6.30*	-1.94
		-2.47	-0.77	-3.13*	-1.75
	First difference	-7.73*	-5.34*	-2.17	-6.07*
		-6.80*	-3.69*	-1.67	-6.66*
An intercept and a linear trend	Level	-4.09*	-1.38	-2.24	-4.41*
		-2.62	-1.08	-2.06	-4.60*
	First difference	-7.70*	-5.70*	-3.29	-6.00*
		-6.89*	-4.18*	-2.49	-6.70*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A14 Dickey-Fuller and Augmented Dickey-Fuller tests: public administration and defence sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	3.07	3.09	-0.98	-0.10
		0.49	0.71	-0.78	0.47
	First difference	-1.55	-1.74	-3.32*	-1.58
		-1.07	-1.22	-2.38*	-0.67
	Second Difference	-6.19*	-6.49*	-7.02*	-6.18*
		-2.77*	-3.03*	-3.69*	-3.16*
An intercept but not a trend	Level	-0.74	-0.61	-1.60	-1.62
		-1.53	-1.40	-1.92	-1.38
	First difference	-1.59	-1.89	-3.29*	-1.39
		-0.93	-1.22	-2.35	-0.33
	Second Difference	-6.13*	-6.40*	-6.85*	-6.22*
		-2.76	-2.99*	-3.59*	-3.23*
An intercept and a linear trend	Level	-0.93	-1.05	-0.51	0.31
		-1.71	-1.80	-1.72	0.05
	First difference	-1.46	-1.76	-3.40	-2.43
		-0.50	-0.84	-2.50	-1.41
	Second Difference	-6.64*	-6.80*	-6.74*	-6.57*
		-3.19	-3.34	-3.51	-3.57*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

Table A15 Dickey-Fuller and Augmented Dickey-Fuller tests: other services sector

		Log(Y/L)	Log (W)	Log(Y/K)	Log (R)
No intercept, no trend	Level	1.65	0.99	6.60	4.01
		1.38	0.72	2.42	1.51
	First difference	-4.12*	-3.78*	-1.68	-1.96
		-2.38*	-2.27*	-1.12	-1.55
An intercept but not a trend	Level	-0.38	-0.50	5.02	3.91
		-0.46	-0.75	2.03	1.13
	First difference	-4.44*	-3.85	-2.26	-2.42
		-2.61	-2.33	-1.69	-2.03
An intercept and a linear trend	Level	-1.58	-1.61	1.34	0.81
		-1.71	-1.84	1.19	0.59
	First difference	-4.35*	-3.75*	-4.26*	-4.17*
		-2.53	-2.20	-4.00*	-4.38*

Note: In each cell, the upper value is the DF statistic, and the lower value is ADF(1) statistic.

*exceeds published critical value

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