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Deagriculturalisation and technical change: A study of crop husbandry in Kerala

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Abstract

The growth of net state domestic product (in constant prices) in agriculture in Kerala shows cyclical fluctuations and currently in deagriculturalisation phase. Modern growth theory pioneered by Solow attributes technological progress as the ultimate driving force behind sustained growth. Without technical progress, diminishing marginal productivity of capital sets in and choke off growth leading to stagnation and/or steady state growth. This hypothesis is examined at the sub sectoral, crop husbandry, level of agriculture due to unavailability of secondary source of data at the aggregative level. Solow's growth accounting method is applied in the estimation of multi-factor productivity growth (MFPG) in crop husbandry in Kerala. The estimates show that the technical progress is very negligible/negative for the four major crops (Paddy, Tapioca, Coconut and Pepper) in Kerala. The Johansen's test for cointegration (JTC)) also confirms that there is no long run relationship between MFPG and output growth for the last thirty-seven years of farming in three crops, i.e., Paddy, Tapioca and Coconut. The fourth crop, Pepper, does not satisfy the necessary condition for JTC. The JTC results on the remaining nine major crops with partial factor productivity growth (PPG) and output growth show: (1) no relationship for five crops, i.e., Rubber, Tea, Cashew, Cardamom, and Arecanut; (2) positive relationship in one crop, Banana; and (3) inapplicable in three crops (Turmeric, Ginger and Coffee) due to mixed order of integration in its time series on PPG and output. Hayami-Ruttan box diagram analysis shows that the two-factor partial productivity (labour and capital) indicator moves in the upward direction for Banana and in the downward direction for Turmeric and Ginger. This implies that former has increasing efficiency and the latter has decreasing efficiency in farming for which cost of cultivation studies are available only for selected years. Solow's basic model of economic growth with migration is provided as an explanation for the current deagriculturalisation phase of agricultural growth in Kerala.

The analysis indicates technical change, the engine of growth, is yet to start in Kerala's agriculture even though the transformation of traditional agriculture has been going on for the last seventy years since independence. The implication is that it is the lack of investment in the adaptation of technological and institutional innovation that was developed and successfully implemented by the presently developed countries and the failure of the regional government to diffuse the adapted technology across the state uniformly.

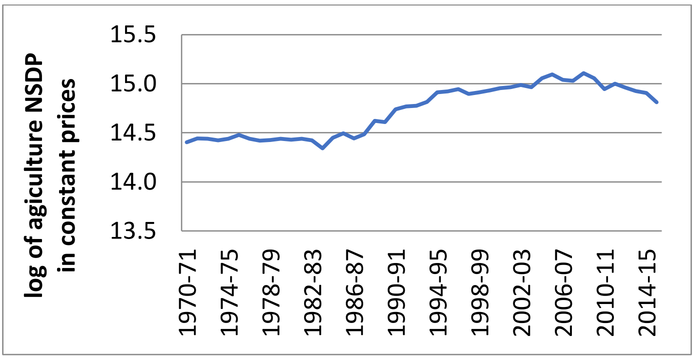
Key words: Deagriculturalisation, multi-factor productivity, growth accounting, cointegration analysis and Hayami-Ruttan box diagram.
JEL Classification: O13, O30, O41, C22

1) Introduction

Modern theories on economic growth began in early mid-1950s with two seminal papers by Solow (1956, 1957), one on the characterisation of steady state growth of an economy producing single good and the other on estimating technical progress using growth accounting methodology with a case study of US for the period, 1909-1949. Solow's contribution also emphasized the role of physical capital accumulation in clarifying modern growth and identified technical progress as the driving force behind sustained economic growth (Jones and Vollrath, 2013; p.2). The quantitative aspects of modern economic growth in rate, structure, and spread of the developed countries mostly in Europe, European offshoots overseas and Japan have the following growth characteristics as observed by Kuznets. The technical progress as measured by the rate of growth of efficiency has been very high and pervasive in all major sectors and is higher in industry than in agriculture. If the large magnitude of efficiency is compared with pre-modern levels, one can infer that there was agricultural as well as industrial revolution during the period, 1880-1980 (Kuznets, 1966; pp.488-490). To what extent such a relationship exists in the less developed countries (LDCs) during the early stages of their transformation of traditional agriculture has not been systematically examined in the literature. This is especially true of at subnational level of large national economies like India. Our main objective in this paper is to fill this gap by investigating the relationship between growth and technical progress in agricultural sector by a case study of Kerala, which has the unique status among Indian states of having social indicators on par with developed nations.

The first task for achieving the objective is to examine whether the region has experienced sustained agricultural growth or not. The trend in the agricultural income (log of net state domestic product in constant prices) for the period, 1970-71 to 2014-15, depicted in Figure 1 is examined for assessing sustainability of growth. The figure indicates that the period from 1970-71 to 1984-85 has no growth (the slope of the trend is parallel to the x-axis) which is the stagnation period as identified by Kannan and Pushpangadan (1988, 1990).

Figure 1: Trend in agriculture NSDP in constant prices, 1970-71 to 2014-15



Source: State income (various issues), Department of economics and statistics, GoK

In the second period, 1984-85 to 1995-96, growth speeds up (increasing), followed by slowdown from 1995-96 to 2005-06 and meltdown in growth from 2005-06 onwards. The last period begins the deagriculturalisation phase of the sector. In other words, the analysis of the growth during the last 45 years suggests that the growth was not sustained as shown by the cyclical fluctuations. According to Solow, this is explainable in terms of diminishing marginal productivity of physical capital without any technological progress in the sector. The task ahead is, therefore, to examine the nature of technical change in agriculture. The literature review suggests that technical progress is measured as multi-factor productivity growth which is the change in the ratio of total outputs to total inputs in the production process. In theory it is a physical measure related to quantities of outputs and inputs, independent of prices of inputs and outputs (Zhao, et al., 2012: p.77). But in reality, factor prices are involved in the weights used for aggregating inputs and outputs for calculating productivity measure. Two standard measures used for estimating productivity are; one is the general measure, i.e., multi-factor productivity (MFP)/total factor productivity (TFP), and the other, partial factor productivity (PFP). Two methods are available in the estimation of MFP: parametric and non-parametric methods (Griliches, 1996; Zhao et al., 2012: p.82). In the parametric case, it is econometrically modelled from production function (a function of all inputs in the production process) using regression analysis and the residual is taken as a measure of total factor productivity. In the non-parametric method, it includes data envelopment analysis, Malmquist and conventional index methods among others. In the present case we apply the non-parametric method of growth accounting with sources of growth as pioneered by Solow (1957). The specific objectives of this paper are:

1) Estimation of technical change as multi-factor and partial productivity of growth of crop husbandry in Kerala; and
2) Examine whether there exists any long run relationship between technical change and output growth in major crops in Kerala

The study is organised as follows. In section 2, literature review for the analysis is undertaken. In the third section, a discussion of methodology and of the data base for the analysis is pursued. Section 4 contains the details on the secondary source of data for the study. The empirical analysis is undertaken in section 5. The technological change based on growth accounting with sources of growth pioneered by Solow is estimated here. It also contains co-integration analysis for examining long run relationship between output growth and technical progress not only in MFPG but also in PPG. This section also contains an application of Hayami-Ruttan Box diagram method in the sort run measurement of two-input partial productivity among crops, The final section, Sixth, provides the summary and conclusions emerging from the study.

2) Literature Review

The study of economic history of today's developed economies points out that the long run sustainable growth recorded by them was only after modernisation of their traditional agriculture in terms of higher levels of production and productivity. The theoretical support for the observed economic growth had to wait until 1956 for Solow's path breaking paper on 'A contribution to the Theory of Economic Growth' (Solow, 1956). The model makes it clear that '… the role of the accumulation of physical capital' and '…the importance of technical progress as the ultimate driving force behind the sustained economic growth' (Jones and Vollrath, 2013; p. 2). In his second paper on technical change and aggregate production function, Solow provides a methodology for measuring technical progress using growth accounting with sources of growth (Solow, 1957). Towards the end of 1950s and early 1960s, the next major analytical advance is made by Schultz (1964; p.4) on 'how to transform traditional agriculture, which is niggardly, into a highly productive sector of the economy'. Schultz's study dismissed all the erroneous assumptions prevailing on traditional agriculture in less developed countries and identified lack of appropriate investment opportunities as the main hindrance to the modernisation of traditional agriculture in the developing world (Schultz, 1964: p.5). Once there are investment opportunities and efficient incentives are created, Schultz argued that 'farmers will turn sand into gold' in such societies. The requirement is to develop and to supply such factors that create low priced income streams for growth. For achieving this objective, he develops a supply and demand approach in determining income streams from agricultural sources. In this approach, the demanders are the farmers and suppliers are profit motivated firms/individuals 'who discover, develop, produce, distribute and thus make demanders available the new set of factors of production' (Schultz, 1964: pp.143-144).

The empirical evidence and the related hypothesis on this transformation to modern growth is then taken over by Kuznets (1966) in his 'modern economic growth: rate, structure, and spread'. His empirical analysis is based on ten developed countries including Italy in Europe, five overseas overshoots of Europe including Union of South Africa and Japan from Asia (Kuznets, 1966: p.505). One significant finding especially relevant to our enquiry is 'that a substantial rise in the productivity of resources in the domestic agriculture is a condition of the large increase in overall productivity in modern economic growth' (Kuznets, 1966; p.120). Although the productivity in agriculture was lower than in industry during this period especially for Japan and USA, it was very large compared with pre-modern times so that one can think of modern growth originated from agricultural as well as from industrial revolution (Kuznets, 1966; p.491). What was the nature of structural transformation implied in the growth process arising from a rise in efficiency? Although efficiency was pervasive among all the production sectors of the developed economies, no general pattern emerged from the productivity growth of the three broad sectors (agriculture, manufacturing, and Services) of the economy. The study observes that the shift in the shares of the three broad sectors are as follows (Kuznets, 1966:pp. 96-97): (1) the share of agriculture sector in total product declined in twelve of the thirteen countries in the study group, (2) the decline is from about 50 % to as low as 20 % points, often over 30 for the long periods under consideration, (3) In twelve countries, the share of the industry in country wide product rose, (4) In the early phase the share was in the range of 20 -30 % and towards of the end of the period it rose to 40-50 %, (5) the share of the service sector is 'neither marked nor consistent among the countries or the long sub periods'. In other words, there is empirical support from economic history for the structural shift towards manufacturing but its impact on service sector is inconclusive. With this Kuznets-Schultz perspective, the next major work in the modernisation of traditional agriculture is the study by Hayami and Rattan in 1971 and its elaborated and extended edition in 1985 titled: 'Agricultural Development: An

International Perspective'. Their central theme of the book is that the technological progress is the engine of sustainable growth during the transition phase of a traditional society. In other words, the technical progress is the pre-condition for sustained growth of the modern economy.

The Literature review on productivity analysis in Indian agriculture indicates that two recent studies are directly relevant for the present study. The first one is by Chand et al. (2011) on 'Total factor productivity and contribution of research investment to agriculture growth in India' and the second by Binswanger-Mkhize and Alwin d'Souza (2012) on structural transformation and agricultural productivity in India. Both studies are on agriculture sector at all India level, the structure of which is different at the sub national level. There is also the danger of 'the fallacy of the aggregation' which implies the sum of the parts does not add up to the whole as warned by Keynes as back as in 1936 (Kumar, 2022; p.75). Moreover, the purpose of the present study is to examine whether the long run relationship between MFP and output exists or not at the sub national level for agriculture using methods in time series econometrics.

3) Methodology

Even though there are several methods of estimating technical progress such as production function approach, TFP accounting and calibration methods (Acemoglu, 2009; p.105), we use growth accounting methodology pioneered by Solow (1957) with the sources of growth instead of the latest technology due to the unavailability of data at the regional level. A brief summary of the methodology and the data base is as follows.

3.1. The growth accounting method for measuring technical progress

The growth accounting method, the production function is specified as:

$$Q= F\ (K, L, N; t) \qquad (1)$$

Where K stands for capital input, L for labour input and N for land input. The variable 't' is a shift parameter for technical change. More specifically it includes "slowdowns, speedups, improvements in the education of the labour force and all sorts of things will appear as technical change" (Solow 1957). Assuming neutral technical change (Hicksian) the production function (1) becomes

$$Q= A(t)\ f(K, L, N) \qquad (2)$$

Where A(t) measures the cumulated effect of shifts over time. Differentiating (2) totally with respect to time and dividing by Q, (2) becomes

$$\dot{Q}/Q = \dot{A}/A + A\ \partial f/\partial K\ \dot{K}/Q + A\ \partial f/\partial L\ \dot{L}/Q + A\ \partial f/\partial N\ \dot{N}/Q \quad (3)$$

Where dots indicate time derivatives. Assuming factors are paid their marginal products, (3) becomes

$$\dot{Q}/Q = \dot{A}/A + w_k\ \dot{K}/K + w_l\ \dot{L}/(L) + w_n\ \dot{N}/N \quad (4)$$

This estimate on $\dot{A}/(A)$ in equation (4) is a of measure technical change which will be estimated for the agriculture sector in Kerala. Next task is to provide the methodology for testing the long run relationship between technical change and output growth. The methodology is discussed below.

3.2 Long run relationship between growth of output and technical change: A co-integration analysis

Cointegration analysis (CIA) is a technique for examining long run behaviour among two or more time series variables. A necessary condition for the test is that all the series should follow unit roots or integration of order unity. The series with unit root is then subjected to Johanasen rank order test for the validity of long run relationship (Enders 2004, p. 396). Unit root (order of integration) tests are administered with and without structural breaks in the literature. There is evidence to show that test without structural breaks is biased (Zivot and Andrews, 1992). The bias in the decision making depends also on whether the break is exogenously or endogenously introduced in the test (Kapetanios, 2005; Narayan and Popp, 2010). The bias will be lower if the unit root test is with unknown endogenous structural break. We use the simplest test, unit root with one unknown endogenous structural break, as developed by Zivot and Andrews (1992). If the necessary condition is satisfied from the unit root test with breaks, then Johansen rank test for cointegration of the two series is applied to know whether there exits any long run relationship.

4) The Data

A review of the secondary source of data for estimating MFP in agriculture at the aggregate level indicates that gross output/value added measure is available from national income accounts. But total inputs, primary and intermediate, are not available on a time series basis except that of total area under agriculture. Therefore, at this level of aggregation, technical change cannot be estimated and its long run behaviour with output growth assessed. Next level of disaggregation of agriculture income is by crop production and by livestock production. The share of crop husbandry in net state domestic product in constant prices in agriculture and allied activities is 65 % in 2011-12 and remaining 35 % is due to livestock production. Two sources of crop production statistics that enable the construction of total input/s for the estimation of technical change/multi-factor productivity are: (1) Economic Review (various issues), Kerala State Planning Board, Government of Kerala (GoK), and 2) Cost of cultivation reports, Department of Economics and Statistics (G o K). But the coverage of crops varies across years and is irregular so that time series analysis of crop production is extremely difficult for all the major crops. The summary of the secondary sources of data on crop husbandry is reported in Table 1.

There are 15 principal crops cultivated in Kerala according to Economic Review, 2016-17. Thirteen out of the fifteen crops have information on area, production and yield at state level for the period from 1958-59 to 2017-18. The thirteen crops cover about 98 percent of total area under principal crops which excludes other plantains and pulses. The reports on cost of cultivation are available only for 4 crops- paddy, coconut, tapioca and pepper- for the period, 1981-82 to 2016-17 except for the three years 1986-87, 1991-92 and 1993-94. The three reports of cost of cultivation are missing in the department of economics and statistics. Our effort to trace them elsewhere in the Kerala collections was unsuccessful so far. The only option left is to substitute the average value of the preceding and succeeding years for the missing years so as to make the time series continuous during the period.

Table 1. Summary of secondary data on crop husbandry in Kerala

Sl. No	Crops	Area and production	Cost of cultivation
1	Paddy	1958-59 to 2017-18	1980-81 to 2016-17
2	Coconut	1958-59 to 2017-18	1980-81 to 2016-17
3	Rubber	1958-59 to 2017-18	NA
4	Banana	1987-88 to 2017-18	1983-84 to 1988-89 and 1997-98 to 2016-17
5	Arecanut	1958-59 to 2017-18	1980-81 to 1984-85, 1992-93 to 1997-98 and 2002-03 to 2016-17
6	Pepper	1958-59 to 2017-18	1980-81 to 2016-17
7	Coffee	1958-59 to 2017-18	NA
8	Tapioca	1958-59 to 2017-18	1980-81 to 2016-17
9	Cashew	1958-59 to 2017-18	NA
10	Cardamom	1958-59 to 2017-18	2014-15 to 2016-17
11	Tea	1958-59 to 2017-18	NA
12	Ginger	1958-59 to 2017-18	1980-81 to 1984-85 and 1994-95 to 2016-17
13	Turmeric	1976-77 to 2017-18	1980-81 to 1982-83 and 1994-95 to 2016-17
14	Pulses	1985-86 to 2017-18	NA
15	Other plantains	1987-88 to 2017-18	NA

Source: (1) Economic Review and Report on Cost of cultivation (various issues), GoK.\

For certain crops data is not collected for the following years as is evident form the Table 1: 1) Banana for the period 1989-90 to 1996-97; 2) Arecanut for the period 1985-86 to 1991-92 and for 1998-99 to 2001-02; 3) Ginger for the period 1985-86 to 1993-94; and 4) Turmeric for the period 1983-84 to 1993-94. We have also excluded the crops such as cowpea, bitter guard and pineapple which are introduced in cost of cultivation surveys since 2014-15 onwards. It is very surprising to know that Rubber, a major crop in Kerala, does not have any cost of cultivation data. Same is true for other major plantation crops- tea, coffee, and cashew as well. There is an urgent need for initiating cost of cultivation studies for assessing the international competitiveness of these crops and to examine the role of technical change in its sustainable growth as recommended by CSO in 2008 as part of introducing new system of national accounts.

The cost of cultivation data is reported on a per hectare basis. Cost components for the state level are projected by the respective area multiplier of the crops. The cost components thus obtained are deflated with appropriate price indexes to arrive at the primary inputs such as labour, capital and land in the production of each of the four crops. Capital cost is deflated by WPI for machinery and machine tools sector with 2004-05 as base year published by the office of the economic advisor, department of promotion of industry and internal trade, Government of India (GoI). The labour input is obtained by deflating labour cost by average annual agriculture wage rates from statistics for planning (various issues), department of economics and statistics and economic review, Government of Kerala (GoK). In the case of cost on fixed capital shows a sharp decline from 1984-85 to 1985-86 for all crops and then stable for the remaining period. This sharp decline is adjusted by splicing the series with 1985-86 as the base year. For this, the value for 1984-85 is projected backward from the series starting with 1985-86 so that the first series can be scaled down to obtain continuous time series on the capital input for the analysis. The primary inputs thus derived are then used for the calculation of MFP reported in the next section.

5) Empirical results

In the empirical analysis, we first take up the estimation of growth accounting with sources of growth for the major crops. The multi-factor productivity growth is estimated and tested for its long run relationship with output growth. This analysis is followed by the long run analysis of partial productivity growth (yield) and output growth of nine more crops. Hayami-Ruttan box diagram technique is applied with two-factor productivity (labour and capital) for assessing the technical progress in the crops that are not amenable to long run analysis due to data unavailability. These investigations are taken up in the next subsections.

5.1 Growth accounting and sources of growth: Solow method

We estimate MFP growth of four crops using the growth accounting framework by applying the equation (4). The primary inputs, capital and labour, are obtained as discussed above from the cost of cultivation data. The intermediate inputs (seed and fertilizers) for which the share is very small is not considered for the analysis due to the unavailability of appropriate price index. The averages growth rate of output and its components for each of the four crops is reported in table 2. The average MFPG, the residual output growth as defined by Solow (1957) and Morrison (1992), is given in the last row of Table 2.

Table 2: Growth accounting and sources of growth for four crops in Kerala, 1980-81 to 2016-17.

Average growth rate (%)	**Paddy**	**Tapioca**	**Coconut**	**Pepper**
Output	-2.56	-1.36	2.00	3.70
Inputs: (i) Labour	-3.62	0.02	1.92	0.58
(ii) Capital	0.32	0.35	0.15	2.76
(iii) Land	-1.35	-3.09	0.56	0.42
MFP = (output-weighted inputs)	2.06	1.36	-0.63	-0.06
MFPG = weighted partial productivity growth (all inputs)	-5.40	-6.04	-	-

Source: Appendix 1, Pushpangadan and Izudheen (2020).

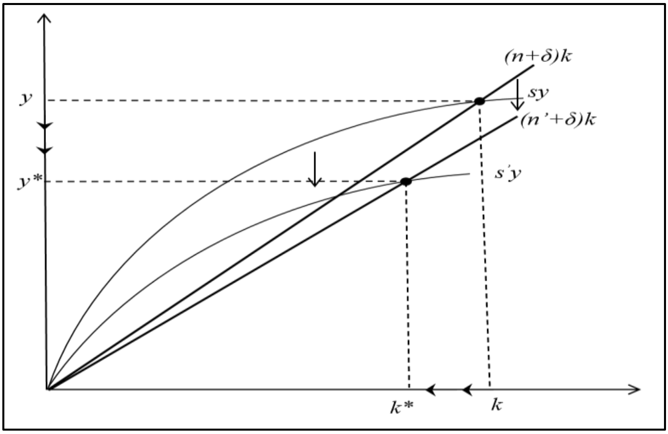
Two crops, paddy and tapioca, record negative growth rates and the other two, coconut and pepper, positive growth rates. In the case of positive growth rates of output, the contribution of MFP growth rates to output growth is negative and very close to zero implying no technical progress has occurred during the last thirty-seven years of cultivation. In the case of crops with negative output growth rates, positive MFPG is not meaningful since it is the definition of MFPG that makes it positive. In this case we have applied an alternative definition of MFPG as the weighted sum of partial productivity growth of all inputs (Murray and Sharpe, 2016). By this definition, both paddy and tapioca have negative MFPG as indicated by the last row of Table 2. In other words, there is no technical progress in the production of the four major crops during the last thirty-seven years of farming. This confirms the earlier findings of negative MFPG in crop production for Kerala by Mukherjee and Kuroda (2003) for the period, 1972-1993. Economic history of presently developed nations suggests that technical progress which had been the 'engine of growth' during early stages of transformation of their traditional agriculture especially in Japan and in US is not valid in the case of the regional economy (Hayami and Ruttan 1985; p.168). The implication is very straight forward, the engine has yet to start its historical role in Kerala. In other words, the green revolution has not made any impact in Kerala's agriculture.

The deagriculturalisation observed in Kerala needs an analytical explanation based on modern theory of economic growth. In his reflections on modern growth theory, Solow maintains that neoclassical growth model has not any competing model in the literature in this regard (Solow, 2005; p.4). The modern economic growth theory began with the pioneering paper by Solow on 'a contribution of the theory of economic growth' in 1956. A simplified version of the model is applied here to explain the deagriculturalisation taking place currently in Kerala.

5.2 Deagriculturalisation: A comparative static analysis of Solow's growth model with migration

In this model, Figure 2, it is assumed that the economy produces a single homogeneous good (output). The simplifying assumption avoids all the complications arising out of the separation of consumption and saving decisions of the real world. In other words, the decision is to decide on how much output is to be saved (consumed) and invested. The two sources of growth in the model are physical capital accumulation and technical change. In the present case, the empirical evidence is that there is no technical change in the sector. The model which is relevant in this case is the basic Solow model without any technical change leaving only capital accumulation as the only determinant of growth.

Figure 2: Comparative statics of Solow's growth model with migration



Source: Adapted from Solow (1957) and Jones & Vollrath (2013)

The basic model has two components as shown in figure 2; one on capital accumulation function (sy), where s is the fraction of output per capita (y) that is invested and the other is (n+δ)k curve, the per capita capital required for keeping the capital-labour ratio constant. The slope of the line is the sum of the growth rate of labour force (n) and the depreciation rate (δ). The equilibrium in this basic model is determined by the intersection of investment function and the per capita capital required to keep the labour constant so that the net capital growth is zero. The initial steady steady state equilibrium at k at which the investment is enough to keep the capital per worker constant and the steady state per capita income is y (Jones and Vollrath, 2013, pp.28-31). Let us examine the comparative statics analysis of an exogenous shock of largescale migration on the steady state equilibrium. The shocks affect both investment rate and the capital stock curve as shown in the diagram. In the short run, it reduces savings rate in the agricultural sector which shifts the investment function downward to s1y. But migration also reduces the domestic supply of labour which rotates capital stock curve to the right of the existing curve to keep capital-labour ratio constant. Clearly the steady state-equilibrium in the post migration period is lower than that of the pre-migration period. The new steady equilibrium has lower capital per capita and lower per capita output, leading to negative growth rate. Our task is to provide empirical support for the lower savings rates in the rural sector in Kerala during the period under study which had witnessed large scale migration to Gulf countries in the 1970s. Migration effect reduces the savings rate of rural households because the cost of migration including their travel and other settlement expenses abroad are met mainly from borrowed funds. After debt repayment, the remittances income will be spent on consumer durables on a hierarchal preference of rural households (Pushpangadan, 2003). This again reduces saving rates of the rural households and corresponding investment in agriculture. Historically, there was no institutional arrangement for channelling rural savings into investment in agriculture which continues to be so after migration as well.

Yet another condition can be derived from factor supply from the per capita production function. Consider the production function, y= kα where y is output per worker, k, capital per worker. Expressing the per capita production function in growth rate form, we have

$\dot{y}/y = \alpha \ \dot{k}/k = \alpha \ (\dot{K} - \dot{L})$

The per capita output growth becomes negative when the growth rate of capital is less than the growth rate of labour force. To what extent this condition is valid during the deagriculturalisation period needs further empirical investigation.

5.3 Long run relationship between multi-factor productivity growth and output growth: Cointegration analysis

The long run contribution of technical change to growth is to be statistically validated. This validation is taken up next by co-integration analysis (Hamilton, 2012). First, the time series on output and MFP have to be generated. The output series is given but not the MFP series. The MFP series is estimated from the series on MFP growth rates by applying the method used by Solow (1957) in his growth accounting framework. The necessary condition for cointegration analysis is that both series (output and MFP) are non-stationary with unity as the order of integration (unit root) for each crop. The standard test is the Dickey-Fuller unit root test which is likely to be biased unless the endogenous structural breaks in the series, if exist, are not adjusted in the calculation of the test statistic (Zivot and Andrews, 1992, Kapetanios, 2005, and Narayan and Popp, 2010). In the present analysis we have used unit root test incorporating one endogenous unknown structural break in the statistical package R devised by Zivot and Andrews (1992). The results are presented in table 3.

Table 3: Zivot-Andrews unit root test with one endogenous structural break by crop in Kerala, 1980-81 to 2014-15

Crops	Variable	No of lags	Test statistics	Table value (5% level)	Order of integration	Break point
Paddy	Output	2	-4.30	-5.57	I(1)	1996-97
	MFP	3	-4.21	-5.57	I(1)	1997-98
Coconut	Output	3	-4.01	-5.57	I(1)	1987-88
	MFP	4	-2.99	-5.57	I(1)	2001-02
Tapioca	Output	1	-5.41	-5.57	I(1)	1994-95
	MFP	1	-4.71	-5.57	I(1)	2002-03
Pepper	Output	3	-3.39	-5.57	I(1)	2002-03
	MFP	1	-6.22	-5.57	I(0)	2009-10

Source: Appendix 1, Pushpangadan and Izudheen (2020).

The table shows that necessary condition for co-integration analysis is satisfied only for three crops, i.e., paddy, coconut and tapioca. In the case of pepper, output series have unit root but not for MFP so that long run test is not applicable. It may be noted that break points are not uniform among the crops.

Since we have only two variables for co-integration analysis for each crop, our null hypothesis is no co-integration against the alternative hypothesis of co-integration. In such situation, there is only one possible relationship between the two variables and an appropriate test is Johansen rank test with λ max criteria (Enders

2005; p. 389). We apply this test to the three crops (paddy, coconut and tapioca) that satisfy the necessary condition of unit root for both series (output and MFP). The results are summarised in table 4.

Table 4. Johansen rank test for co-integration of output and MFP by crop

Crops	**Eigen value**	**λ max**	**Table value**	**Long run relationship**
Paddy	0.218	8.606	15.67	No (Accept the null hypothesis of no relationship)
Coconut	0.321	13.549	15.67	No (Accept the null hypothesis of no relationship)
Tapioca	0.176	6.775	15.67	No (Accept the null hypothesis of no relationship)

Source: Appendix 1, Pushpangadan and Izudheen (2020).

The results show that there is no long run relationship between technical change and output growth in none of the three crops for which multi factor productivity estimates are available. This provides econometrics support for the growth accounting findings on technical change in the regional agriculture.

Next, we examine the relationship between partial productivity growth (yield) and output growth using the same test as above.

5.4. Long run relationship between partial factor productivity growth and output growth

Even though the partial factor productivity has the severe limitation of ceteris paribus assumption, which is quite unlikely to be valid in the long run, it can still be used for extending the coverage of more crops in the CIA analysis. From Table 1, it is clear that PFP (yield) series is available for nine crops in the state for the period, 1958-59 to 2017-18. The long run relationship is examined by repeating the same cointegration analysis as in section 5.2 for nine crops. To begin with, Zivot and Andrews unit root test with single endogenous break is administered and the results are reported in table 5.

Table 5: Zivot and Andrews unit root test with one endogenous structural break by crop in Kerala, 1958-59 to 2014-15

Sl. No.	Crops	Variables	No of lags	Test statistics	Table value (5% level)	Order of integration	Break point
1	Rubber	i. Output	2	-2.46	-5.57	I(1)	2006-07
		ii. Yield	2	-2.96	-5.57	I(1)	2011-12
2	Turmeric	i. Output	1	-6.63	-5.57	I(0)	1993-94
		ii. Yield	1	-9.17	-5.57	I(0)	1994-95
3	Tea	i. Output	2	-4.62	-5.57	I(1)	2000-01
		ii. Yield	2	-2.97	-5.57	I(1)	1982-83
4	Coffee	i. Output	4	-4.01	-5.57	I(1)	1997-98
		ii. Yield	2	-5.64	-5.57	I(0)	1982-83
5	Cashew nut	i. Output	1	-3.26	-5.57	I(1)	1987-88
		ii. Yield	1	-3.97	-5.57	I(1)	1975-76
6	Cardamom	i. Output	1	-4.8	-5.57	I(1)	1992-93
		ii. Yield	1	-3.86	-5.57	I(1)	1992-93
7	Banana	i. Output	1	-4.95	-5.57	I(1)	1978-79
		ii. Yield	1	-5.51	-5.57	I(1)	1978-79
8	Ginger	i. Output	1	-4.59	-5.57	I(1)	1987-88
		ii. Yield	3	-7.7	-5.57	I(0)	1969-70
9	Arecanut	i. Output	1	-2.12	-5.57	I(1)	2011-12
		ii. Yield	1	-2.13	-5.57	I(1)	2012-13

Source: calculated from Appendix 2, Pushpangadan and Izudheen (2020).

Result shows that all nine crops have unit roots in both output and yield series except turmeric, coffee and ginger. This would mean that only 6 crops satisfy the necessary condition for cointegration analysis. As in the previous section, Johansen rank test with λ-max is applied for assessing the long run relationship between PFP growth and output growth for six crops and results are summarised in table 6.

Table 6: Johansen rank test for cointegration by crop

Sl. No.	Crops	Eigen value	λ max	Table value	Long run relationship
1	Rubber	0.245	15.46	15.67	No
2	Tea	0.164	9.85	15.67	No
3	Cashew	0.16	9.59	15.67	No
4	Cardamom	0.108	6.29	15.67	No
5	Arecanut	0.209	12.89	15.67	No
6	Banana	0.269	17.23	15.67	Yes

Source: Appendix 2, Pushpangadan and Izudheen (2020).

The results show that even with partial factor productivity (PFP) which assumes all other inputs remain the same during the period, only one crop, Banana, has long run relationship between output growth and growth in yield. But the relationship needs validation with MFP of the same crops as and when such measures are available. This is partly because PFP is a misleading measure when input substitution, technological improvements are embodied in other inputs, among others, are incorrectly assigned to improvements in the input (Zao et al., 2012; p.80). The analysis is incomplete if we don't examine the nature of productivity of the remaining three crops: ginger, coffee and turmeric. Next, we analyse the relationship between two-factor productivity (labour and capital) as a short run measure of technical change keeping factor proportions (capital-labour ratio) constant by applying Hayami-Ruttan box diagram method in the next section .

5.5 Two-factor productivity, technical progress and factor proportions: turmeric, coffee and ginger.

Among the three crops, only turmeric and ginger, have the data for Hayami- Ruttan (H-R) box diagram analysis (Hayami and Ruttan, 1985: p.121; and Fuglie et al., 2012:p.2).

5.5. Since coffee is a plantation crop, it is not included in the cost of cultivation studies and could not be included in the box diagram analysis in the absence of input data. Banana is included because it is the only crop which shows a positive relation between technical progress and output growth in the partial productivity analysis (see table 8). In the H-R box diagram labour productivity (Y/L, Y stands for output and L stands for labour) is in the x-axis and capital productivity (Y/K, K stands for capital) in the y- axis both measured in logarithmic scale.

For the interpretation of H-R box diagram in figure 5, following decomposition formula is applied:

$Y/K = (Y/L) \times (L/K)$, where Y is output, K, capital and L, labour.

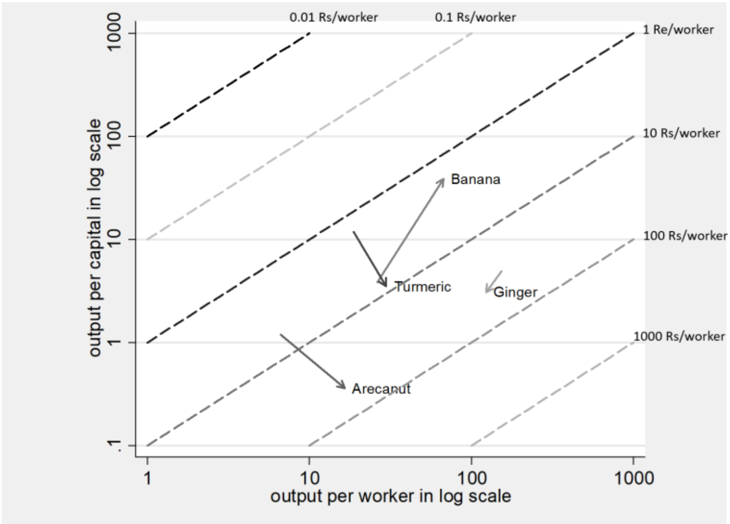
Taking logarithm of both sides,

$$\text{Log}\,(Y/K) \equiv \log\,(Y/L) + \log\,(L/K) \qquad (5)$$

If labour-machine ratio remains constant in equation (5), change in labour productivity is equal to change in capital productivity without any change in the factor proportions. Otherwise, any change in capital productivity is equal to the change in labour productivity plus change in the factor endowment as reflected in the inverse of capital-labour ratio. Eq. (5) clearly establishes the relationship between the productivity of capital and labour for given labour intensity. Obviously, if both partial productivity measures increase then more output is produced for the same level of capital and labour. The advantage of two-input partial productivity index is that it can be measured for even two data points. The application of this short run measure is illustrated in Figure 3.

For each crop, two triennium averages (TA) were obtained first; one for the beginning point and the other for the ending point. The TA for the beginning years for the three crops- arecanut, ginger and turmeric- are;1994-95, 1995-96 and 1996-97. In the case of banana, the TA is for the three years; 1987-88, 1988-89 and 1989-90. The TA for ending three years are the same for all the four crops; 2014/15, 2015/16 and 2016/17. Hayami-Ruttan Box diagram for the four crops is given in Figure 3.

Figure 3: Hayami-Ruttan Box diagram for two-factor partial productivity (labour and Capital) for four crops, Kerala



Source: Appendix 3, Pushpangadan and Izudheen (2020).

It may be noted that if the arrow in figure 3 is parallel to the uni. K-L line and both PFPs are increasing, then more output is produced with the same level of inputs without any change in factor proportions. Such a case indicates technical progress. Although no such crop exists in figure 3 but banana comes very close to it. Moreover, the arrow of Banana indicates the increase in capital productivity is more than that of labour productivity, the difference is due to the change in K/L ratio. Ginger shows decline in efficiency since both PFPs are in the down ward direction. The arrows of Arecanut and Turmeric move towards the right direction with negative slope as per figure 3. In such cases, productivity of labour is increasing more than that of capital. More over the efficiency is decreasing in the production of both crops. The micro foundation of this relationship can be found only in endogenously determined technical change instead of exogenously determined as assumed in the present analysis. Such an enquiry needs separate treatment of both in theory and in measurement, which is beyond the scope of the present paper.

Our study shows that technical change as measured by total factor productivity growth (TFPG) has not taken place in crop husbandry in Kerala since 1980. The state level analysis of TFPG in agriculture undertaken by Mukherjee and Kuroda (2003) for the period, 1972-1993, shows that two states, Kerala and Gujarat, have no technological progress but only regress during the period. Our results validate the same trend since 1993 except for the crop Banana, which is not even 3% of the total area under cultivation in Kerala in the year 2016-17. However, the success story of this crop, Banana, needs documentation for any lessons to be learned so that it becomes part of any future public policy for undertaking technical and institutional innovation for sustained growth (Hayami and Ruttan, 1985; chapter 4). Detailed R&D expenditure is required to develop appropriate technology suitable locally and /or adapt from the other developing/developed countries such as Japan, USA, South Korea, Taiwan, Israel, etc., where agriculture played or continues to perform the historical role of 'the engine of growth' for their sustained growth and development.

6) Summary and conclusions

6.1 Summary

The agricultural growth as measured by net state domestic product (in constant price) in Kerala shows that the unstable growth as shown by stagnation, acceleration, slow down and melt down since 1970s. Our concern is current deagriculturalisation phase as indicated by the melt down of growth (negative) starting from 2005-06 onwards. Modern economic growth theory pioneered by Solow attributes technological progress as the ultimate driving force to sustained growth. This would mean that sustained growth occurs only if long run relationship exists between technical progress and agriculture growth. Empirical verification of this hypothesis needs time series data on technical progress and output growth at the sectoral level. The standard measure of technical progress is the change in multi-factor productivity. In order to estimate it at the aggregate level, we need information on total inputs (capital, labour and land) and total value added (output) of the sector. The output measure is available at the sectoral level from national income accounts but no secondary source exists for primary inputs. Therefore, the analysis can be undertaken only at next level of sectoral disaggregation. The next level of disaggregation in national accounts is: (1) crop husbandry and (2) animal husbandry. The share of former in national income originating from agriculture is 65 % and the latter 35 % in 2011-12. The secondary source of data shows that the input index can be estimated for crops from the cost of cultivation reports published by government of Kerala. Such an estimation is not possible for the sub sector, animal husbandry. Thus, the severity of data availability restricts present study to crop sector alone for the estimation of TFPG.

Solow's growth accounting with sources of growth is applied for the estimation of MFPG from cost of cultivation data. Out of the fifteen major crops cultivated in Kerala only four of them have time series data on cost of cultivation starting from 1980-81 to 2016-17. The growth accounting method indicates that only two crops-coconut and pepper- have positive output growth on an average and the residual growth rate of output growth is negative for the period under study. The MFPG of paddy and tapioca as the weighted average of partial productivity index of all inputs also shows negative growth rate during the period. The long run relationship between technical progress and growth of output is examined by applying co-integration analysis (CIA).

The necessary condition for CIA is that the two series (output and MFP) of each crop have unity as the order of integration.

Unit root test with one endogenous structural break as developed by Zivot and Andrews (1992) is administered for all four crops. The Zivot and Andrews (Z-A) test shows that the necessary conditions are satisfied only for three crops; paddy, tapioca and coconut. The fourth crop, pepper, does not satisfy the necessary condition for CIA. The three crops were subjected to Johansen rank test with λ-max for the validity of long run relationship between output growth and MFP growth. The results do not support long run relationship between technical change and output growth for the three crops. Since pepper has mixed stationarity {output, I(1) and MFP , I(0)}, the CIA is not applicable.

More crops can be included for testing the long run relationship, if we consider partial factor productivity (PFP) such as land productivity (yield) as a proxy for MFP as an indicator of technical change. The secondary source of data indicates that PFP is available for nine more crops from 1958-59 onwards. The long run relationship of remining nine crops is examined by applying the same methodology as in the case of MFP. The Z-A unit root test is administered for nine more crops as in the case of above four crops and the result shows that six of them satisfy the necessary condition for CIA. As in the previous case, Johansen rank test with λ-max criterion is applied for testing the validity of long run relationship between output and yield for more six crops. Even with such an imperfect measure of partial index for technological change only one crop, banana, satisfies long run relationship for sustained growth. The result on banana based on PFP is to be validated with MFP as and when such information is available. The three crops that do not have unit roots in output and PFP are turmeric, coffee and ginger which needs other methods for assessing technical change.

We apply Hayami and Ruttan box diagram method for four crops (Arecanut, banana, ginger, and turmeric) with two-partial productivity measure one for labour and the other for capital. The arrow of banana in figure indicates that increase in capital productivity is more than that of labour productivity, the difference is due to decrease in K/L ratio. Since its arrow is pointing upward it indicates increase in efficiency. Ginger shows decline in efficiency by both PFPs. The arrows of arecanut and turmeric move towards the right direction with negative slope. In such cases, productivity of labour is increasing and that of capital is decreasing. But overall efficiency is decreasing.

6.2 Concluding remarks

The analysis indicates that there is no evidence of long run relationship between technological change and output growth in crop production in Kerala. The lack of long run relationship of output either with MFP or with partial factor productivity in most of the crops is the major source of deagriculturalisation phase of agriculture growth in Kerala. It clearly shows that green revolution has not even touched our agricultural sector unlike in other parts of India. From the modern theory of economic growth and from growth empirics, technical progress as the engine of growth is yet to start in Kerala even though transformation of the traditional agriculture has been going on for the last seventy-five years since independence.

Our challenge is to introduce endogenous technical and institutional change in agriculture as an essential part of modernisation process. Such a strategy requires exclusive R & D expenditure for generating endogenous technical and institutional changes and its diffusion throughout Kerala. To begin with, a survey on indigenous technology and intuitions should be undertaken and its use among famers be assessed. If the existing techniques of production do not reflect the scarcity of inputs, then a component of R&D must be devoted to directed technological change wherein the relatively expensive inputs are economised (Acemoglu; 2009: p. 527). Yet another strategy is to adapt the technology developed by the countries such as Japan, USA, Taiwan, south Korea, Israel, etc. who had successfully completed or in the process of achieving it. Above all, the third tire of government(panchayati Raj instituions) must be part of the institutional arrangement for the transformation process. The entire policy framework and the machinery for the structural transformation of early stages of development cannot be better stated than the one by Hayami and Ruttan (1985) as in their influential study on agricultural development with an international perspective. To quote:

> "The critical element in this process is an effective system of market and non-market information linkages among farmers, public research institutions, private agriculture supply firms and political and bureaucratic entrepreneurs. … that the proper functioning of such interaction is a key to success in the generation of the unique pattern of technical change necessary for agriculture development in any developing economy" (Hayami and Ruttan 1985, p.5)

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