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Sources of Growth in Pulses Production in India

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Abstract

This paper has analyzed the patterns and sources of growth in pulses production in India and has examined their implications for future growth of pulses production. The study has observed an increasing trend in pulses production, driven mainly by yield improvements. The contributions of area expansion and prices to pulses growth have been erratic, suggesting that these can not be the sustainable sources of growth in pulses. Further, farmers' area allocation decisions to pulses are not price-dependent, but depend on non-price factors, mainly rainfall. These findings imply that in the short-run, to boost pulses production, the policy should address the non-price constraints such as irrigation, access to credit and input supply. However, the growth in pulses production in the long-run must come from technological changes.

Key words: Pulses, growth, area substitution, yield response, irrigation

JEL Classification: D24, D21, O33, O13

Introduction

India, with a share of 22 per cent, is the largest producer of pulses in the world. But the production of pulses has not been able to keep pace with their domestic demand, resulting in imports of 2-3 million tonnes of pulses per annum. For the two decades, post-1991, pulses production is almost stagnated at around 14 million tonnes, leading to a significant decline in their per-capita availability, from 61g/day in 1951 to 42 g/day in 2012 — one-third less than the recommended intake of 65g/day (ICMR, 2013). Further, the mismatch between demand and supply has made the pulses market more volatile.

Closing the gap between demand and supply of pulses would require production to grow at least by 4 per cent per annum (Kumar, 1998; IIPR, 2011). To achieve this rate, the Government of India started an Accelerated Pulses Production Program (A3P) in 2007-08, and has also laid considerable emphasis on pulses production under the National Food Security Mission (NFSM) that was launched in 2007-08. The focus of both these programs has been on alleviating supply-side constraints, including biotic and abiotic stresses, and enhancing seed replacement rates. With this backdrop, the paper has examined (i) the pattern and sources of pulses production to see whether these efforts have yielded the desired results; and (ii) the supply response of pulses to price and non-price factors.

Data

The data for the period 1990-2012 on area, production, and yield of pulses were compiled from the *Indian Agricultural Statistics*, and *Agricultural Statistics at a Glance*; on farm harvest prices were collected from *Agricultural Prices in India*; on cost of cultivation and minimum support prices were taken from reports of the Commission on Agricultural Costs and Prices; and on rainfall were taken from *Rainfall*

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Statistics. Wherever needed, these data were supplemented with data from other sources. The farm harvest prices and production costs were converted into real prices at 2004-05 prices. The time series data on area, production, and prices were smoothed by applying Hodrick-Prescott filter with an adjustment factor of 6.25. The Hodrick-Prescott filtered data series were used for analyzing the patterns and sources of growth.

Methodology

Decomposition of Growth

For computing sources of growth, the approach outlined in Minot *et al.* (2006) was followed. According to this approach, the change in gross revenue from a single crop can be decomposed into (i) change in cropped area, (ii) change in yield, (iii) change in real price, and (iv) a residual representing the interaction among these. These sources of change or growth in gross revenue are influenced by a number of economic and non-economic factors. For instance, a change in the total cropped area could be due to the changes in weather conditions, irrigations, industrialization, and urbanization, among other factors. The crop yields are influenced by biotic and abiotic stresses, technology, water availability, input levels; and soil health, and farm prices are influenced by policies, world prices, etc. (Birthal *et al.*, 2014).

Assuming that a farmer behaves rationally, he or she maximizes profit from his or her land by choosing a production mix, inputs, and technologies subject to his resource endowments and market conditions. If A_i is area under crop i, Y_i is its production per unit area, and P_i is the real price per unit of production, then the gross revenue R can be decomposed as:

$$\partial R \cong \left(\sum_{i=1}^{n} Y_i P_i\right) \partial \left(\sum_{i=1}^{n} A_i\right) + \left(\sum_{i=1}^{n} A_i\right) \left(\sum_{i=1}^{n} (Y_i \partial P_i) + \sum_{i=1}^{n} A_i \sum_{i=1}^{n} (\partial Y_i P_i)\right) \quad \ldots(1)$$

Equation (1) decomposes the change in gross revenue due to changes in (1) cropped area, (2) crop yield or technology, and (3) real prices. The first-term on the right hand side represents the change in gross revenue due to a change in cropped area. The second-term captures the change in gross revenue due to a change in real prices. The third-term provides the effect of change in crop yield or technology. Dividing both sides of Equation (1) by δR gives us the proportionate contribution of each source in the overall change in gross revenue or output growth.

Substitution Effect

There could be a shift in area from pulses to other crops or vice-versa or even within different pulses depending on their relative profitability and other factors. The dynamics of area substitution between pulses and other crops was analyzed using first-order Markov Chain Model (MCM) that generates transition probability matrix in a linear programming framework. The general form of the first-order MCM is given by Equation (2) :

$$a_{jt} = a_{jt-1} p_{ij} + u_{jt} \quad \ldots(2)$$

where, a_{jt} is the area under j^{th} crop in the year t; a_{jt-1} is the area under j^{th} crop in the year t-1; and p_{ij} is the probability of area shifts from crop i to crop j. The transitional probability p_{ij} lies between zero and 1, i.e., $0 \le p_{ij} \le 1$. The p_{ij} is estimated using the method of minimization of mean absolute deviation, as:

$$\text{Min } \mathbf{0}p^* + I\varepsilon$$

$$\text{Subject to } xp + \varepsilon = y$$

$$gp = 1, p^* \ 0$$

where, p* is a vector of probabilities, p_{ij}, **0** is a vector of zeros, I is an identity matrix of appropriate dimension, ε is the vector of absolute errors, x is a block diagonal matrix of lagged values of y, and g is a grouping matrix to add the row elements of p arranged in p* to unity.

Supply Response

Most of the time series have unit root problem and are often suspected to be non-stationary. To overcome this problem, we tested for stationarity by using Augmented Dickey-Fuller (ADF) test (Dickey and Fuller, 1981). The method of Cointegration and Error Correction Mechanism (ECM), when combined with the partial adjustment and adaptive expectation of farmers, gives the distinct long-run and short-run supply elasticities (Townsend and Thirtle, 1995). This technique can be used with non-stationary time series to avoid spurious regression (Banerjee *et al.*, 1993). The ADF test is denoted by Equation (3):

$$\Delta X_t = \mu_0 + \mu_1 t + (\delta - 1)X_{t-1} + \sum_{i=1}^{k} \varphi_i \Delta X_{t-1} + e_t \quad \ldots(3)$$

where, e_t is the pure white noise error-term and k is the chosen lag length. The null hypothesis H_0 holds that $\mu_1=0$ against alternative hypothesis H_1 that if H_0 is rejected, then the series (X) is stationary. If not, the first difference is taken to make it stationary.

Once the stationarity of individual series is established, linear combinations of integrated series are tested for cointegration. If these are found co-integrated, it implies a long-run equilibrium relationship. The analysis is carried out by applying Johansen and Juselius (1990; 1992) cointegration test which involves the VECM framework of the following form:

$$\Delta X_t = C + \sum \alpha_j \Delta X_{t-1} + \delta D_t + \gamma T + \lambda \varepsilon_{t-1} + \upsilon_t \quad \ldots(4)$$

where, $\varepsilon_{t-1} = \ln X_{t-1} - \sum \beta_j \Delta X_{jt-1}$ (error/equilibrium correction-term), and D_t is a vector of stationary exogenous variables; δ is vector of parameters of exogenous variables; and λ is the coefficient of error correction- term ε_{t-1}.

A co-integration analysis is the equation of long-run relationship among co-integrated series or the variables contained in X_t. The Johansen approach provides two test statistics for the number of co-integrating vectors given by the co-integration rank r: Trace and the Maximum Eigen Value statistics. When the co-integration rank r is equal to 1, the Johansen single equation dynamic modelling and the Engle-Granger approaches are valid. When r equals 1, the normalisation restriction for the parameters produces a unique estimate (Golinelli and Rovelli, 2002). When there are more than one co-integration equations, the Johansen approach is preferred over Engle-Granger approach (Kremers *et al.*, 1992; Thiele, 2003).

Once the cointegration among the variables is confirmed, the ECM is used to analyze the short-run and long-run dynamics. The ECM is dynamic in the sense that it involves lags of the dependent and explanatory variables, and thus captures short-run adjustment to the changes in adjustments into past disequilibria and contemporaneous changes in the explanatory variables and also displays the co-integrating relationship between or among variables.

The adaptation agricultural supply response is modelled as a two-step procedure. A farmer first decides on the area allocation to a crop based on its expected price and then yield response is estimated as a function of different inputs and climate.

$$A_{it} = f(RP_i, AR_i, D, T)$$

$$Y_{it} = f(GIR_i, CoC_i, AR_i, T)$$

where, A_{it} is the area allocated to the i^{th} crop during year t; RP_i is the relative price, which is the ratio of farm harvest price of the i^{th} crop to the farm harvest price of its competing crop; AR_i is the actual average rainfall during i^{th} crop growing period; D is a dummy variable to reflect a structural break in the series and was identified using Quandt-Andrews unknown breakpoint test by regressing area or yield on real farm harvest prices; GIR_i is the i^{th} crop gross area irrigated (ha); CoC_i is the variable cost of cultivation per ha of the i^{th} crop, and T is the time trend.

Results and Discussion

Status of Pulses Production

In 2011-12, India produced 17.88 Mt of pulses from an area of 24.78 Mha (Table 1a). Over time, there has been an increase in pulses production mainly due to improvement in their yields; the average yield increased from 595 kg/ha in 2001-02 to 724 kg/ha in 2011-12. Table 1b provides the disaggregated information on pulses by growing period, i.e. *kharif* (June-September) and *rabi* (October-March). The *rabi*-pulses account for half of the total pulses area and contribute close to two-thirds to the total production, and these proportions have not changed much over time, indicating no significant seasonal shift in pulses production. However, a faster increase has been observed in the average yield of *rabi*-pulses in the recent decade; it increased at an annual rate of 2.91 per cent during 2002-2012 as compared to 0.12 per cent in the previous decade of 1992-2002.

The production of pulses, however, is concentrated in a few states in India. The states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh and Karnataka account for more than 70 per cent of the total area as well as production of pulses (Table 2). Madhya Pradesh has a higher share in the *rabi*-pulses. It alone accounts for one-third of the total production. On the other hand,

Table 1a. Season-wise area, production and yield of pulses in India, 1982-2012

TE Period	Area (Mha)			Production (Mt)			Yield (kg/ha)		
	Kharif	*Rabi*	Total	*Kharif*	*Rabi*	Total	*Kharif*	*Rabi*	Average
1982	10.37	12.67	23.04	4.07	7.26	11.33	392	574	492
	(45.0)	(55.0)		(35.9)	(64.1)				
1992	10.95	11.14	22.09	5.15	7.87	13.02	472	666	572
	(48.2)	(51.8)		(39.5)	(60.5)				
2002	10.78	11.20	21.98	4.47	7.37	11.84	465	720	595
	(49.1)	(50.9)		(37.9)	(62.1)				
2012	11.61	13.17	24.78	6.36	11.52	17.88	548	881	724
	(46.8)	(53.2)		(35.6)	(64.4)				

Note: The values within the parentheses indicate percentages.

Table 1b. Season-wise compound annual growth rate for area, production and yield of pulses in India, 1982-2012

Periods	Area			Production			Yield		
	Kharif	*Rabi*	Total	*Kharif*	*Rabi*	Total	*Kharif*	*Rabi*	Total
1982-1992	0.54	-0.98	-0.25	1.67	0.02	0.66	1.13	1.02	0.91
1992-2002	-0.73	-0.64	-0.69	-1.83	-0.52	-1.06	-1.11	0.12	-0.38
2002-2012	0.56	1.80	1.21	2.41	4.76	3.93	1.84	2.91	2.69
1982-2012	0.09	0.04	0.07	0.53	1.13	0.91	0.43	1.08	0.84

Table 2. Share of states in total area and production of pulses (Average of 2008-09 to 2012-13)

(in per cent)

	Rabi		*Kharif*		Total pulses	
State	Area	Production	Area	Production	Area	Production
Andhra Pradesh	8.83	9.92	7.28	6.15	8.13	8.65
Bihar	3.79	3.97	0.59	1.26	2.35	3.06
Chhattisgarh	4.85	4.17	2.02	1.36	3.57	3.22
Gujarat	1.78	2.02	5.30	7.48	3.37	3.86
Karnataka	8.07	5.60	12.32	10.62	9.98	7.30
Madhya Pradesh	29.93	32.72	10.25	9.77	21.06	24.97
Maharashtra	10.04	9.28	19.41	23.6	14.26	14.11
Rajasthan	10.40	10.30	23.78	16.14	16.43	12.29
Tamil Nadu	3.12	1.41	1.55	1.50	2.41	1.44
Uttar Pradesh	11.63	13.83	8.11	10.99	10.04	12.87
Others	7.56	6.74	9.39	11.13	8.40	8.23

Maharashtra and Rajasthan have higher shares in *kharif*-pulses; together they contribute 40 per cent to the total production of *kharif*-pulses. Further probe shows that though pulses have a wider regional spread, there are niches for different pulses. Chickpea production is concentrated in Madhya Pradesh (40%), Rajasthan (13%) and Maharashtra (12%); green gram is concentrated in Rajasthan (41%) and Maharashtra (23%); pigeon-pea is concentrated in Maharashtra (33%) and black gram is concentrated in Uttar Pradesh (25%), Madhya Pradesh (20%) and Maharashtra (17%). This indicates the need for crop- and region-

Table 3. Categorization of states as per the compound growth rate (total pulses)

Period	Area		Production		Yield	
	Positive	Negative	Positive	Negative	Positive	Negative
1982-1992	AP, GJ, KR, MH, UP	BR, MP, RJ	BR, AP, GJ, KR, MH, MP	RJ, UP	BR, AP, MH, MP	GJ, KR, RJ, UP
1992-2002	AP, KR, MH	BR, GJ, MP, RJ, UP	AP, KR, MH	BR, GJ, MP, RJ, UP	BR, AP, KR, MH, MP	GJ, RJ, UP
2002-2012	GJ, KR, MP, RJ	BR, AP, MH, UP	BR, AP, GJ, KR, MH, MP, RJ	UP	BR, AP, GJ, KR, MH, MP, RJ, UP	

Note: AP: Andhra Pradesh, BR: Bihar, GJ: Gujarat, KR: Karnataka, MP: Madhya Pradesh, MH: Maharashtra, RJ: Rajasthan and UP: Uttar Pradesh.

specific strategies for enhancing pulses production in India.

To discern spatial changes in the performance of pulses, based on decadal growth rates in area, production and yield, states were classified as (i) those experienced positive trend, and (ii) those experienced negative trend during the sub-periods (Table 3). Madhya Pradesh that had experienced a negative trend in area during 1980s and 2000s, depicted a strong positive growth during 2002-2012. On the other hand, in states like Andhra Pradesh and Maharashtra, the area trend turned out to be negative, but yield growth remained positive. This could be attributed to the government intervention, such as dissemination of high-yielding varieties and integrated pest and nutrient management practices under NFSM and A3P program.

Sources of Growth

The gross value of output of major pulses was decomposed into (i) area effect, (ii) yield effect, and (iii) price effect. The results are presented in Figure 1 (a), (b), (c), (d) and (e) for chickpea, pigeon pea, black gram, green gram and lentil, respectively. The area effect for all these pulses, except black gram and green gram, was stronger especially after the interventions through NFSM and A3P. The area expansion accounted for 21 per cent of the output growth in the case of chickpea, 13 per cent in the case of pigeon pea and 15 per cent in the case of lentil during 2008-2012. This might be due to the promotion of rainfed farming techniques in right perspective and reallocation of resources in terms of finance and technological services in corresponding with the requirement of the production niches.

The effect of yield has also exhibited a varied picture. The yield effect was observed prominent for black gram and green gram in recent years. The increasing yield effect might be due to the technological improvement in the agronomical practices of the respective pulse crops, whereas the declining share of yield effect could be the reason of yield drag.

The effect of prices on growth has been declining continuously particularly during the 2000s. The price effect though declined, it still accounted for more than 50 per cent of the growth. This shows that farmers are not aligned to prices, and their decisions are influenced more by non-price factors such as technologies or improved varieties, infrastructure and market access. Reddy and Mishra (2009) have concluded that though the growth in farm harvest price (FHP) or minimum support price (MSP) has shown a favourable price regime to chickpea compared to other crops, but it failed to evoke a proportionate response. It could be inferred that the production response to price in pulses, in general, is rather weak and non-price factors such as high-yielding /modern varieties, technology, better infrastructures including adequate procurement system, etc. are more important for accelerating pulses production in general.

Dynamics of Area Substitution of Pulses

Madhya Pradesh, being the largest producer of pulses, was purposively selected to capture the holistic picture of area substitution. Dynamics of area

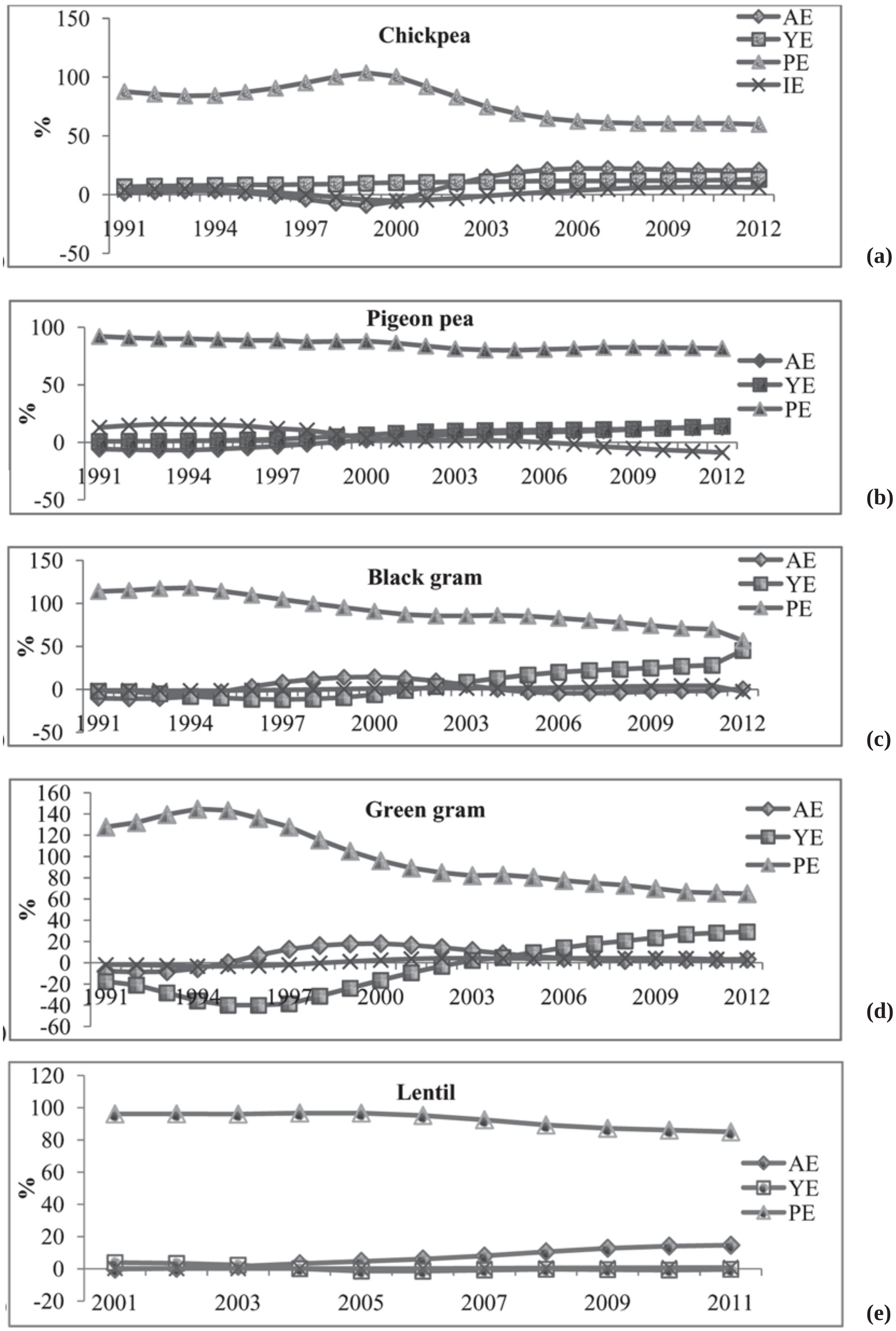

Figure 1. Decomposition of gross return of (a) chickpea (b) pigeon pea (c) black gram (d) green gram, and (e) lentils, respectively in India, 1991-2012

Table 4a. Dynamics of area substitution between crop groups in India and Madhya Pradesh, 1990-2012

	Crop groups India					Crop groups – Madhya Pradesh			
	P	Ce	O	Co		P	Ce	O	Co
P	35.70	5.51	52.51	6.28	P	27.82	6.49	27.32	38.37
Ce	2.96	49.86	43.91	3.27	Ce	0.01	90.96	9.03	0.00
O	43.15	4.51	47.51	4.83	O	0.60	0.00	48.53	50.87
Co	5.41	0.05	4.53	90.02	Co	2.38	0.00	7.25	90.37

Source: Authors' calculation
Note: P=Pulses, Ce=Cereals, O=Oilseeds, Co=Cotton,

Table 4b. Dynamics of area substitution within pulses crops, 1990-2012

	Pulses–India						Pulses–Madhya Pradesh				
	C	P	B	G	L		C	P	B	G	L
C	**23.44**	23.51	3.74	4.88	44.43	G	**25.52**	11.45	38.33	8.70	15.99
P	4.55	**48.47**	36.90	0.00	10.08	A	0.05	**59.65**	0.03	40.24	0.02
B	42.10	0.00	**51.52**	0.00	6.39	U	6.17	0.00	**75.93**	9.56	8.34
G	0.17	21.07	7.37	**28.30**	43.09	M	2.59	6.62	4.44	**85.79**	0.56
L	13.87	0.30	31.06	12.22	**42.55**	L	6.89	0.20	33.75	1.12	**58.04**

Source: Authors' calculation
Note: C=Chickpea, P=Pigeon pea, B=Black gram, G=Green gram, L=Lentil

substitution within pulses and between crop groups during 1990-2012 (India and Madhya Pradesh) has been presented in Tables 4a and 4b. The first order Markov chain model (MCM) was used to determine transition probability matrix (TPM) to explain how area between pulses and other crops as well within pulses has shifted over the years (1990-2012). The rows of matrix show the area of the corresponding group lost to the other crop groups, whereas the columns indicate area gained by the respective crop group. The results show that during 1990-2012 pulses could retain only around 36 per cent of their area at all-India level and gained 43 per cent of area from oilseeds, whereas in Madhya Pradesh, these retained 28 per cent of the area, and gained marginally from other crop groups (Table 4a). At all-India level, 52 per cent and 6 per cent of the pulses area was substituted by oilseeds and cotton, respectively. While in Madhya Pradesh, 27 per cent and 38 per cent of pulses area was lost to oilseeds and cotton, respectively. The area lost to cereals was not substantial. These findings indicate that oilseeds compete with pulses in India. The observed substitution between pulses and oilseeds/cotton might be promising because of the similarities in the production requirement, including climatic conditions and inputs as the entire crop groups are mostly grown in marginal land rather than on productive area and under rainfed conditions as compared to cereals crops. The TPM has also shown that the preference for cereals was distinct over pulses, oilseeds and cotton, as no significant area of cereals was shifted to other crops.

Area Substitution within Pulses

The transition probability matrix (TPM) in percentage terms (Table 4b) has reflected the area substitution within pulses. The results reveal that almost all the pulses retained more percentage of their area in Madhya Pradesh than at all-India level. At all-India level, chickpea retained only around 23 per cent of its area and lost around 44 per cent and 24 per cent of its area to lentil and pigeon pea, respectively. In Madhya Pradesh, it retained around 25 per cent of its area and lost 16 per cent to lentil and 38 per cent to black gram. The substitution with black gram is as expected as it is also cultivated during *rabi* season in many states and Madhya Pradesh is not an exception. Within the pulses, black gram was able to retain the highest area of its own. In India during 1990-2012, pigeon pea was sharing its area with black gram and green gram, while in the state it was losing and gaining area of cultivation from green gram.

Supply Response of Chickpea in Madhya Pradesh

Area Response

Before applying VECM, it is ensured that area series are co-integrated. Appendix Table 1 shows the results of cointegration rank test with the trace statistics and maximum eigen value. The combination shows the area function that included chickpea area and relative price. Both the test statistics rejected the hypothesis of more than one cointegrating vector at 5 per cent level of significance, indicating that there exists a single and unique cointegrating vector between the concerned variables in the area equation. The optimal lag length is four lags for area equation. When only one cointegrating vector exists, its parameters can be interpreted as estimates of long-run cointegrating relationship between the concerned variables (Hallam and Zanoli, 1993). Thus, the area model has one cointegrating vector. The normalized cointegrating equation for area of chickpea in Madhya Pradesh is:

$$A = 7.6204 + 0.2929RP_c + 0.0052T$$

The value of coefficient for relative price of chickpea with respect to the price of wheat in terms of area allocation of Madhya Pradesh in the long-run is positive but statistically non-significant. Similarly, the technological advancement indicated by the trend variable is positive but non-significant. This indicates that in the long-run farmers are price-insensitive. The coefficient of trend variable as a proxy of various historical investment and technological improvement was not able to provide incentives to the farmers. The chickpea crop in Madhya Pradesh is grown under the rainfed conditions which may be the reason regarding the price-insensitive behaviour of farmers in the state.

Table 5 shows the VECM estimates of area response of chickpea to its relative price and rainfall. In the short-run relationship, the significance of negative error correction coefficient (-0.847) as expected suggests that about 84 per cent of deviation from long-run equilibrium is made up or adjusted within one time period. It also implies that the speed with which price of chickpea adjusts from short-run disequilibrium to changes in chickpea supply in order to attain long-run equilibrium is 114 per cent within one year. The coefficient of price is negative and non-significant, whereas the coefficient of rainfall is positive and significant at 1 per cent level. This implies that the farmers value rainfall more than the price in their area allocation decisions. The significant coefficient on year dummy indicates that after 2008 the area allocation has improved, which may be the positive effect of government interventions. The result is also consistent with the fact that in the recent period area effect has contributed most to the growth of chickpea in the state.

Yield Response of Chickpea

Appendix Table 3 shows that hypothesis of unit-root problem in the first difference of all the series involved in the estimation is rejected. The series integrated of the order one was estimated by the VECM. The normalized cointegrating equation for yield of chickpea is:

$$Y = -22.694 + 0.796GIR^{**} + 4.04CoC - 0.022T$$

In the long-run, coefficient of gross irrigated area under chickpea, as expected, has shown a positive and significant impact on the yield of chickpea. But, the coefficient for cost of cultivation (CoC) (A1 cost included all the cash and in kind expenditure incurred in purchasing the inputs required for the cultivation) of chickpea was positive with yield of chickpea, but the result was non-significant. The A1 cost variable has contradicted the hypothesis. Since chickpea is grown in the marginal land, the effects of inputs like fertilizer, plant protection chemicals may not be the concern of farmers. The trend variable (proxy of technological change and institutional intervention) has shown a negative and non-significant impact on yield. This implies that the technological change in long-run may have a favourable and distinct impact on the yield of chickpea in Madhya Pradesh.

Table 6 shows the yield response of chickpea to the A_1 cost of cultivation, gross irrigated area and rainfall. The significance of negative error correction coefficient (-0.453) at 10 per cent level of significance, as expected, suggests that about 45 per cent deviation from the long-run equilibrium is made up within one year period. It also implies that the speed with which A_1 cost of cultivation adjusts from the short-run disequilibrium to changes in chickpea yield in order to

Table 5. Area response of chickpea (VECM approach)

Long-run		Short-run	D (ln Area)	
		Error correction	Coefficient	P-value
ln Area(-1)	1	**Cointegration Eq(1)***	-0.847	0.000
ln RP(-1)	0.2929	D(lnArea(-1))	0.460	0.145
TREND	0.0052	D(lnArea(-2))	0.249	0.114
Constant	7.6204	**D(**lnRP(-1))	-0.123	0.217
		D(lnRP(-2))	0.0162	0.867
		Constant	-0.281	0.001
		ln AR*	0.0656	0.002
		Dummy2008**	0.0902	0.017

Diagnostic test		Autocorrelation LM test	Residual test	
			LM-Stat	P-value
R-squared	0.81	LM - $\aleph^2(1)$	3.345	0.501
Adj. R-squared	0.70	LM - $\aleph^2(2)$	1.252	0.869
F-statistic	7.45	LM - $\aleph^2(3)$	4.661	0.323
Akaike AIC	-2.55	LM - $\aleph^2(4)$	2.563	0.633
Schwarz SC	-2.15	Jarque-Bera normality test	2.213	0.696
		Heteroskedasticity tests (Chi-sq)	42.298	0.330

Notes: D = difference
* and **indicate the significance of coefficient at 1 per cent and 5 per cent levels, respectively.

attain long-run equilibrium is 45 per cent within one year.

It can be observed from the results that gross irrigated area is positive and significant at 10 per cent level, whereas the A_1 cost of cultivation is negative but non-significant. The rainfall has shown a positive and significant influence over the yield. This implies that chickpea being grown in *rabi* season, responds positively to the increased number of irrigations and rainfall during the growth and pod formation stages. The negative and non-significant impact of A_1 cost of cultivation, used as proxy of prices of all the important inputs, resembles the farmers' perception regarding chickpea and other pulses as a secondary crop and cultivated in the rainfed conditions in marginal land. It shows that in the rainfed agriculture, irrigation is must in order to integrate farmers to the market.

Summary and Conclusions

In recent years, India from an area of 24.78 Mha has achieved pulses production to the tune of 17.88 Mt, which is a record because pulses production was never beyond 13-15 Mt during the period 1982-2002. *Rabi*-pulses with a higher share in area and production, have shown a higher yield for all the periods studied. The growth rate in total pulses was positive (1.21%) in the period 2002-2012. The substantial positive growth rate of *rabi*-pulses during 2002-2012 resulted in a higher growth rate of 3.93 per cent in production of total pulses. The record pulses production in the recent period has been due to the positive impact of government interventions like increasing government thrust in technological advancement, rapid and intensive extension services, and institutional support through different intervening programs like NFSM-Pulses and A3P. The decomposition analysis of sources of growth has revealed that prices of different pulses, as one of the sources of growth, had a declining share, however, the rate of decline was found decreasing in the recent period. This might be due to the ineffective procurement of pulses by the government agencies. The MSP of pulses, announced by the Government of India is not percolating to the farmer's level so as to influence his decisions.

Table 6. Yield response of chickpea (VECM approach) in Madhya Pradesh

Long-run		Short-run	D (ln Yield)	
		Error correction	Coefficient	P-value
ln Yield (-1)	1	Cointegration Eq1***	-0.453	0.087
ln GIR (-1)**	0.796	D(ln Yield(-1))	-0.187	0.580
ln CoC (-1)	4.040	D(ln Yield(-2))	-0.325	0.140
TREND	-0.022	D(ln GIR(-1))***	0.190	0.070
Constant	-22.694	D(ln GIR(-2))	1.143	0.320
		D(ln CoC(-1))	-1.015	0.120
		D(ln CoC(-2))	-0.952	0.410
		Constant	-0.238	0.011
		ln AR***	0.057	0.089

Diagnostic test			Residuals test	
		Autocorrelation LM test	LM-Stat	P-value
R-squared	0.823	LM - $\aleph^2(1)$	7.613	0.57
Adj. R-squared	0.695	LM - $\aleph^2(2)$	8.563	0.47
F-statistic	6.429	LM - $\aleph^2(3)$	7.652	0.56
Akaike AIC	-1.500	LM - $\aleph^2(4)$	11.791	0.22
Schwarz SC	-1.050	Jarque-Bera normality test	4.718	0.58
		Heteroskedasticity tests (chi-sq)	91.679	0.61

Note: ***indicates significance at 10 per cent level.

In the study, the price has not appeared to be major source of growth of pulses. The area as a source of growth has shown an increasing trend in chickpea, pigeon pea and lentil, but it has been found declining in black gram and green gram. The yield as a source of growth, except lentil, has been found prominent in black gram and green gram while marginal effect has been observed in chickpea and pigeon pea in the same period. The substitution between pulses and oilseeds at all-India level has been observed, while pulses competed with oilseeds and cotton in Madhya Pradesh. Within pulses, almost all could retain more percentage of their area in the state than at all-India level for the recent period.

The area response model has shown that farmers growing chickpea in Madhya Pradesh detect non-price factors better than price factors. The area allocation decision is primarily affected by the rainfall. Technological advancement and different institutional support in long-run in the form of various interventions through different national programs have not been able to put on a reasonable breakthrough in chickpea production in the state. Chickpea production in Madhya Pradesh depends not solely on price or cost factors but is influenced by the climatic conditions (rainfall) and irrigation. Unless there is assured irrigation, the farmers would depend on weather conditions which are highly erratic and uncertain. The coping strategies against the anomalous weather conditions should be strengthened by conducting farmer-focused workshops, trainings along with strengthening the extension and institutional support and services. The risk coping strategies framed under NFSM-Pulses, A3P and other interventions and the farmers' ability to cope with various weather and abiotic stresses should be reinforced by integrating them with the market and providing them with adequate advance information.

The public investment on infrastructure like irrigation in case of pulses production is vital and should be addressed well in such programs and policies. Area and yield response provide an insight to the policymakers about how farmers have entrenched in production system through adjustment in crop keeping into view of limits and bounties of production environment which would be more prone to conscious decision-making. To boost domestic supply of pulses, strategies containing non-price factors like irrigation, access to credit and adequate input supply at affordable price apart from pulses research and extension, need to be devised by the policymakers and planners.

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Appendix Table 1. Unit-root test (ADF) for chickpea area and relative price at level and first difference

Variable	Level				First difference*			
	Without trend		With trend		Without trend		With trend	
	t-statistics	p-value	t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
Chickpea area (ln area)	-2.0469	0.2663	-3.2315	0.1041	-6.4925	0.0000	-6.2825	0.0003
Chickpea relative price (ln relprice)	-3.9605	0.0069	-3.2046	0.1160	-5.6036	0.0003	-5.4252	0.0018
Actual rainfall (ln rainfall)	-4.0630	0.0052	-4.2087	0.0161	-6.9973	0.0000	-6.8168	0.0001

*Note:**indicates that the variables involved in area response model didn't posses the problem of unit-root at their first difference.

Appendix Table 2. Johansen cointegration test for chickpea area and relative price

Unrestricted cointegration rank test (Trace)					Unrestricted cointegration rank test (Maximum eigen value)		
Hypothesized no. of CE(s)	Eigen value	Trace statistics	Critical value 0.05	Prob.**	Max-eigen statistic	Critical value 0.05	Prob.**
None *	0.815	39.873	25.872	0.0005	35.417	19.387	0.0001
At most 1	0.191	4.456	12.517	0.675	4.455	12.517	0.675

*Note:**denotes rejection of the hypothesis at 5 per cent level of significance and indicates the presence of 1 cointegrating vector between the study variables.
**Mackinnon-Haug-Michelis (1999) p-values

Appendix Table 3. Unit-root test (ADF) at level and first difference of selected variables for yield response

Variable	Level				First difference*			
	Without trend		With trend		Without trend		With trend	
	t-statistics	p-value	t-statistics	p-value	t-statistics	p-value	t-statistics	p-value
Chickpea yield (ln yield)	-3.862	0.00	-5.308	0.00	-6.255	0.00	-6.066	0.00
Chickpea gross irrigated area (ln GIR)	-1.178	0.66	-3.242	0.10	-5.66	0.00	-5.545	0.00
Actual rainfall (ln rainfall)	-4.073	0.00	-4.218	0.00	-7.014	0.00	-6.833	0.00
Cost of cultivation (A_1) (ln coc)	-4.929	0.00	-4.912	0.00	-4.329	0.00	-4.326	0.00

Note: *indicates that the variables involved in yield response model didn't posses the problem of unit-root at their first difference.

Appendix Table 4. Johansen cointegration test for chickpea yield, gross irrigated area and cost of cultivation

Unrestricted cointegration rank test (Trace)					Unrestricted cointegration rank test (Maximum eigen value)		
Hypothesized No. of CE(s)	Eigen value	Trace statistics	Critical value 0.05	Prob.**	Max-eigen statistic	Critical value 0.05	Prob.**
None *	0.8300	62.9520	42.9152	0.0002	37.2182	25.8232	0.0010
At most 1	0.5280	25.7338	25.8721	0.0520	15.7658	19.3870	0.1555

Note: *denotes rejection of the hypothesis at the 0.05 level and indicates the presence of 1 cointegrating vector between the study variables.
**Mackinnon-Haug-Michelis (1999) p-values