Studies in Agricultural Economics

Volume 118, Number 2

Contents

Manuscripts should be prepared in English and sent via e-mail to the Editor-in-Chief at studies@aki.gov.hu.

The cost of printing this issue is supported by the Hungarian Academy of Sciences.

1463 Budapest, POB 944, Hungary
https://www.aki.gov.hu/studies
ISSN 1418 2106 (printed)
ISSN 2063 0476 (electronic)
Established 1962

Foreword

The audience of *Studies in Agricultural Economics* is composed primarily of researchers, academics, policy makers and practitioners in agricultural economics and rural development, especially in eastern central and south eastern Europe. On pages vii-x of this issue of the journal we are very pleased to report the establishment of a new initiative of interest to the same audience, namely *BioEast*.

BioEast is a strategic research agenda with two themes. The first is *climate change challenges in the Continental and Pannonian Bio-geographical Regions*. These regions, which cover most of eastern central and south eastern Europe, are likely to be very sensitive to the impacts of climate change, with agriculture, forestry and freshwater aquaculture being particularly severely affected. The second theme is *policy and governance challenges in the economically less developed EU regions*. Much of the *BioEast* region is composed of post-socialist economies that are still undergoing transition, and these economies continue to face unique challenges.

The strategic research agenda has been developed through a range of events, including the Budapest workshop and conference described in this issue. It is to be submitted to the European Commission, which has indicated that it would welcome such an initiative for its EU-wide benefits.

The two themes of *BioEast* are broken down into 13 topics, and several of these are reflected in the papers included in this issue of *Studies in Agricultural Economics*.

Generation change in the agri-food sector is a major concern, and the determinants of farm succession in Polish agriculture are analysed by Dudek. He distinguishes three types of succession, inter-generational, intra-generational and reverse inter-generational, with the first type being the most common. The process has contributed to the balanced age of farmers and the preservation of the rural settlement network in Poland, but has limited land concentration.

Closely associated with generation change is the issue of knowledge-based farming. Bjerke analyses the performance of Swedish agricultural firms with a view to determining how different types of knowledge, internal and external to the firm, affect productivity. She concludes that knowledge matters for the Swedish agricultural sector. Formal education is important and has a higher value added if it is related to the sector itself.

Knowledge, and knowledge sharing, are strongly linked to the topic of cooperation between actors. In the first of two Hungarian papers in this issue, Biró, Hamza and Rácz evaluate the development of different forms of vertical and horizontal cooperation. Large integrator companies, in partnership with smaller 'intermediate integrators' that have local knowledge and direct links with farmers, play a major role in the organisation of agricultural cooperation in Hungary.

The second Hungarian paper is the first of two that addresses the issue of climate change impacts on agriculture. Potential yields of winter wheat and maize in Hungary for the next three decades were modelled by Fogarasi, Kemény, Molnár, Keményné Horváth, Zubor-Nemes and Kiss using representative Hungarian FADN data. A slightly decreasing trend in the yields of both crops is estimated, but precise impacts depend on the climate scenario adopted.

Singh and Narayanan studied the impact of the changing climate on cropping patterns in Andhra Pradesh, India since 1971. Winter temperatures, summer rainfall and annual rainfall distribution are among the factors that have influenced temporal and spatial shifts in cropping patterns at State and Regional levels. Measures such as improving cropping intensity and technology adoption can assist sustainable diversification of the crop sector in the State.

The final two papers were submitted by researchers from CGIAR. Adoption of improved cassava varieties is shown by Feleke, Manyong, Abdoulaye and Alene to have resulted in an approximately 10 percentage point reduction in the poverty rate in four African countries, with an estimated 24,309 households having moved out of poverty. Adoption of the technology has especially benefitted non-poor and female-headed households.

Achandi and Mujawamariya identify the factors affecting market participation by smallholder rice farmers in Tanzania. These include the cropped area on the farm, yield, distance to the market and type of variety grown. Reflecting the findings of the previous two papers, the importance of technology adoption, such as tractors and power tillers, for area expansion and yield improvement is identified.

Studies in Agricultural Economics is pleased to be aligned with the *BioEast* strategic research agenda and especially welcomes papers on *BioEast*-related research topics for future publication.

Andrew Fieldsend
Budapest, July 2016

Michał DUDEK*

A matter of family? An analysis of determinants of farm succession in Polish agriculture

In this paper the impact of selected determinants on farm succession in Poland is analysed. The study shows that socio-demographic factors associated primarily with the characteristics of families, particularly of farm managers, had a significant influence on the family transfers of agricultural holdings. The impact of micro-economic and spatial factors on farm succession was observed as well. However, the research results indicate different scales and characters of succession determinants. Behind this variability was an institutional change linked to Poland's accession to the European Union and changes in the economy. The paper argues that this context, along with conducive social and legal background, reinforced a generational change in the sector. Analysis at the micro level was prepared on the basis of empirical data from the longitudinal IERiGŻ-PIB surveys conducted in 76 villages located across Poland with the use of multinomial dependent variable logit models. A unique feature of the study is an exploration of farm succession as an intra-family and generational phenomenon, relating to the different phases of family life cycle, as well as to kinship relationships. Moreover, unlike the majority of succession studies, the presented research distinguishes three types of succession (inter-generational, intra-generational and reverse inter-generational) and is based on information concerning actual changes in surveyed rural households, not only respondents' declarations about the future.

Keywords: farming family, farm manager, socio-economic determinants, accession to the EU

* Instytut Ekonomiki Rolnictwa i Gospodarki Żywnościowej – Państwowy Instytut Badawczy, Świętokrzyska 20, 00-002 Warszawa, Poland. michal.dudek@ierigz.waw.pl

Introduction

In the agricultural economics literature, the issue of farm succession has been widely analysed for several decades. The problem has been the subject not only of empirical research, but also of policy and public debate (Lobley and Baker, 2012). The analysis suggested that the pace of generational change in agriculture has slowed considerably in recent years. As a result, in many European countries the population of farmers is aging rapidly (EC, 2012). The reasons for this phenomenon are related to general demographic processes (e.g. increase in life expectancy), the reluctance of young people to take over the farms and the unwillingness of older managers to transfer them (Copus *et al*., 2006). Generational change in agriculture is also limited by the increasing costs of setting up a business (especially because of the high land prices), weakening the socialisation into agricultural occupations in rural families, as well as a significant income gap between farming and non-farming branches of the economy (EC, 2013a; Fischer and Burton, 2014). Therefore, it is even argued that the farm succession process in Europe is in crisis, and that this could threaten the economic competitiveness of family farming as well as its sustainability, as well as the viability of rural areas in many countries and regions (Burton and Fischer, 2015). In order to foster generational change in the agricultural sector, the European Union (EU) has undertaken policy interventions (Zagata and Sutherland, 2015). For instance, programmes and instruments aiming at encouraging older farmers to hand over their agricultural holdings or exit from farming (the early retirement programme) were implemented in many EU Member States. At the same time, under the Common Agricultural Policy (CAP), young people entering farming receive substantial financial support for setting up a business and an increased rate of direct payments (EC, 2013b).

Contrary to many other EU Member States, the problem of farm succession has not so far concerned the Polish agricultural sector. In the majority of cases this process runs smoothly. The average age of Polish farmers was among the lowest in the EU and the age structure was considered as balanced[1] (Dudek, 2013). The reasons behind the favourable age structure and efficient transfers could be attributed not only to demographics (entry into the sector of the 1980s baby boom generation) but above all to a conducive socio-economic and institutional context. Thanks to different benefits, older and younger farming family members were usually eager to use appurtenant to them a legally and socially accepted right to hand and take over a patrimony. The majority of agricultural holdings – often very small in economic size – were kept in close family because their residential, security and investment functions (Sikorska, 2013a). For the ex-managers and their successors, farm ownership was a way to gain additional money (e.g. from rent charge, direct payments) or a chance to benefit from a favourable social security and tax system designed for farmers (Wojewodzic, 2013). As a result, owing to limited land resources the existence of a large group of uncompetitive and very small farms in Poland created a barrier to the development of other holdings aimed at commercial production. That is why in the economic debate the necessity of support for further structural changes is highlighted (Kołodziejczyk, 2015). As one way of improvement of land distribution, the activation of a market mechanism in land turnover (i.e. exits from farming) to a much greater extent instead of family transfers is indicated (Sikorska, 2013b).

A number of factors influencing farm succession have been reported. These concern economic, social, demographic, institutional and territorial determinants at the macro and micro levels. As succession is a complex phenomenon of passing the farm within a group of people linked with special ties (mainly kinship), research focused on its different composition and size, as well as social, demographic and

[1] In 2010 the indicator of age structure in EU agriculture (ratio between percentage of farmers less than 35 years old and percentage of farmers 55 years old or older) reached the highest level for Poland and amounted to 0.52. The average value of this value for the EU-27 was 0.14.

personal characteristics. Particularly, these analyses referred to the features of farm managers (Kimhi and Lopez, 1999; Glauben *et al*., 2004a). However, much research on succession has been conducted in countries where market-oriented farms dominate. In such cases, special attention was devoted to the features of agricultural holdings, such as economic potential (area of land, number of livestock, size of capital assets), type of farming or the level of on-farm specialisation (Stiglbauer and Weiss, 2000; Kimhi and Nachlieli, 2001; Glauben *et al*., 2004b; Väre 2007; Mishra *et al*. 2010). It was argued that due to the market competition and constant structural changes in the sector, it was these characteristics that had an impact on continuation or discontinuation of farming activity in subsequent generations. Apart from social and economic determinants, the various rates and timings of succession were explained by territorial location as well as different institutional context. The role of location could be summarised by saying that the family transfer of farms was usually smoother in agricultural regions with favourable environmental, climatic and cultural conditions (Bika, 2007). The relevant institutional system covering legal norms (agricultural and civil law, tax, social insurance) as well as customs and values affected farming families' attitudes to agriculture and defined their role in the economy (Klank, 2006; Calus 2009).

In Poland, despite the communist collectivisation policy before 1989 (which was imposed on a relatively small scale and reflected "a Polish road to socialism" in the Eastern Block) and later market transformation and modernisation of the agri-food sector, family farms remained the dominant organisational unit of agricultural production (Halamska, 2015). However, in the last decade, Polish family farming has undergone significant structural changes. According to official statistics, labour resources[2] decreased by nearly one tenth and the number of holdings[3] by one fifth (from 2.0 to 1.6 million) (Sikorska, 2013a). These decline rates dropped even faster than in the previous decade. Alongside these processes the number of farms decreased in all size groups with the exception of the largest category (units of 30 ha and more), although this process did not translate into a significant change in the size distribution of farms[4]. Moreover, the average size of farm in Poland increased only slightly (from 8.4 to 9.8 ha), and considerable regional differences persisted[5]. As a result, the process of polarisation into two groups of farms – the small and semi-subsistence majority (more than two thirds of the total) and a relatively larger, market-oriented minority (less than one third of the total) has continued.

One of the important reasons behind the preservation of a dual (polarised) structure of family farming was the popularity of transfers of business ownership and managerial control between generations in the two mentioned groups (Sikorska, 2014). In this context, this paper aims to define the latest level, patterns and determinants of succession in Polish agriculture. In particular, the impact of socio-economic factors on family farm transfers is analysed along with changes in a broader context of this process. The accession of Poland to the EU as one of its relevant conditions is considered.

Figure 1: Location of villages and the size of the IERiGŻ-PIB research sample in 2011, in macro-regional distribution.
Source: IERiGŻ-PIB

Methodology

The data on farm succession used in this paper were taken from the comprehensive research carried out by the Institute of Agricultural and Food Economics – National Research Institute, Warszawa (IERiGŻ-PIB) in 2000, 2005 and 2011 in the same 76 villages located across Poland (Sikorska, 2013a). In this survey the sampling of the villages was purposeful so that the area of analysed agricultural holdings reflected the actual area structure of family farms both at the national and macro-regional level.

Five macro-regions are distinguished in the IERiGŻ-PIB studies (Figure 1): (I) Central-Western, (II) Central-Eastern, (III) South-Eastern, (IV) South-Western and (V) Northern (Figure 1)[6]. This territorial division reflects the historically embedded economic characteristics of domestic agriculture and the basic socio-demographic features of the rural population. The samples covered all rural households with the user of agricultural holding in the analysed locations, namely 3,927 farming families in 2000, 3,705 in 2005 and 3,331 in 2011. The samples both in terms of the whole and within each macro-region covered approximately one five

[2] The number of people working on family farms (per full-time employed person equivalent) dropped from 2.2 in 2002 to 2.0 million in 2010.

[3] According to the Agricultural Census 2010, 99 per cent (1.6 million) of all agricultural holdings were family farms. They covered 86 per cent of all agricultural land area in Poland. In the text the term 'family farm' is considered as a farm owned by natural persons, with an area of more than 1 ha of agricultural land.

[4] The share of the category of smallest agricultural holdings (up to 5 ha) in total amounted to 55 per cent.

[5] In Poland, the average farm size is higher in the western and northern parts of the country (from 13 to 30 ha of agricultural land) than in its the eastern and southern parts (from 4 to 12 ha).

[6] The individual macro-regions correspond to the following descriptions and *voivodeships* (NUTS 2 level): (I) Central-Western: Kujawsko-Pomorskie and Wielkopolskie; (II) Central-Eastern: Mazowieckie, Lubelskie, Łódzkie and Podlaskie; (III) South-Eastern: Małopolskie, Podkarpackie, Śląskie and Świętokrzyskie; (IV) South-Western: Dolnośląskie, Lubuskie and Opolskie; (V) Northern: Pomorskie, Warmińsko-Mazurskie and Zachodniopomorskie.

hundredth of the actual number of agricultural holdings in Poland[7]. The large sample size and a wide range of gathered information in the panel IERiGŻ-PIB studies enable trends and changes in family agriculture, including the succession processes to be determined.

In this paper, succession was defined as both a transfer of legal farm ownership and management power related to the agricultural production assets that occurred within the family (household) (Gasson and Errington, 1993). The basic criterion for this categorisation was a change of agricultural holding's manager and owner, as well as its generational aspect. Owing to the specificity of Polish agriculture which plays a role of 'social buffer' in the economy, multiple forms of transfer take place. Apart from traditional inter-generational successions where parents hand over the farm to a younger family member (child), other types of transfers are observed, namely: intra-generational and reverse inter-generational succession. The former refers to a situation when a farm succession occurred within the same generation of the family (e.g. between a spouses in order to obtain a pension[8]). The latter concerns farm transfers from the younger to the older generation (for instance when a son leaves a village to work in an urban area). Moreover, this classification includes both the different phases of the development of farming families and the links between their members according to the rule of descent.

In agricultural economics, the succession of agricultural holdings has most often been analysed based on econometric methods (Mann, 2007). The ways of modelling this phenomenon usually take the form of non-linear models. However, the clear majority of studies on this phenomenon are cross-sectional, taking into account one moment of time (Hennesy and Rehmann, 2007). The succession is not, however, a one-off event but usually extends for many years. The conditions, course and consequences of this process apply to the longer period of time. Hence, for analysing this issue the data from panel studies are far more adequate. Owing to the limited availability of such information and high costs its gathering, cross-sectional surveys have been widespread so far. In such studies a potential succession, taking into account only the plans (declarations) of farmers or their successors, are considered (Viira *et al*., 2014). The personal changes in both management and ownership (i.e. actual succession) was possible in this study because of the availability of the IERiGŻ-PIB panel data from the same farms covering two periods (2000-2005 and 2005-2011). Another original feature of the approach towards succession used here is consideration of its generational and intra-family dimensions. The analysis of the determinants of succession considered the demographic characteristics of the respondents and the family ties between them. This has allowed three types of succession to be distinguished, reflecting various phases of the development of the agricultural family. Therefore, the succession has been operationalised as the multinomial unordered dependant variable (Gruszczyński, 2002). In order to measure the impact of the selected determinants on succession in two periods, multinomial dependent variable logit models were used. The variables analysed in the study are listed in Table 1.

[7] In the total sample, 595 farms were transferred within a family in the period 2000-2005. They covered 4,828 ha of agricultural land (14.5 per cent of the total). At the same time, 383 farms (covering 1,984 ha, i.e. 5.9 per cent of the total) were liquidated. In turn, in 2005-2011 the succession referred to 240 agricultural holdings with an area of 1,955 ha of land (5.7 per cent of the total), while 505 farms (with an area of 3,023 ha – 8.8 per cent of the total) were liquidated.

[8] In Poland one of the condition of getting a full agricultural pension is to leave farming.

Results

The level and determinants of farm succession in Poland

The total succession rate varied from 15 to 7 per cent of all surveyed farms (Table 2). The frequency of each succession type was also different. Nevertheless, the most common was inter-generational succession, covering from two thirds to three quarter of all family transfers in the sample. The share of intra-generational successions was stable but relatively low,. amounting to 2 per cent of the total sample of farms. The frequency of reverse inter-generational successions was marginal. What is important is that the data indicated that the total level of succession was inversely

Table 1: Definition and description of variables used in the logit models of farm succession.

Variable	Variants
Characteristics of the farming family and farm manager	
manager's age	in years
manager's sex	1 – woman; 0 – man
manager's marital status	1 – free; 0 – married
manager's level of education	1– higher; 0 – else
manager's agricultural education	1 – yes; 0 – no
manager's off-farm employment	1 – yes; 0 – no
manager's work at farm	1 – full-time; 0 – else
use of early retirement	1 – yes; 0 – no
number of children in the family (according to kinship)	number of children
type of family (single household)	1 – single household; 0 – else
use of social public support	1 – yes; 0 – no
Characteristics of the farm	
located in Central-Western macro-region	1 – CW; 0 – else
located in South-Eastern macro-region	1 – SE; 0 – else
located in South-Western macro-region	1 – SW; 0 – else
located in Northern macro-region	1 – N; 0 – else
distance to nearest town	in kilometres
size of farm	in ha of agricultural land
lease land	in ha of agricultural land
uncultivated land	in ha of agricultural land
value of commercial agricultural production	in thousand PLN
contract sales of commercial production	1 – yes; 0 – no
number of livestock	in large units
high level of machinery equipment	1 – yes; 0 – no
plan of liquidation	1 – yes; 0 – no
value of agricultural investments	in thousand PLN
agricultural credit	1 – yes; 0 – no
production specialisation	Herfindahl-Hirschman Index
specialisation: wheat	1 – yes; 0 – else
specialisation: dairy cattle	1 – yes; 0 – else
specialisation: fruit	1 – yes; 0 – else
specialisation: industrial plants	1 – yes; 0 – else
specialisation: pigs	1 – yes; 0 – else

Source: own elaboration

associated with the scale of farm liquidation[9]. When the frequency of the former was relatively high, the rate of the latter was low (period 1). In turn, the opposite relationship was observed in period 2.

The research results have documented the various impacts of different determinants on farm succession (Table 3). In the years characterised by a high rate of total farm family transfers, eight statistically significant determinants supporting this process were noted. When the succession scale was relatively lower (period 2), the factors hampering that phenomenon became particularly important (nine had negative and statistically significant impacts).

Regardless of the time span, the strongest and statistically negative influence on succession was linked with the situation of family, in particular in case of single households. Such cases limited the probability of inter-generational family transfers, *ceteris paribus*, from 86 to 94 per cent (Tables 4 and 5). On the other hand, the inter-generational successions of agricultural holdings were likely to happen when managers lived with other persons to whom it was possible to hand over the production assets. Particularly, this situation referred to the children of farmers but only to the period when total succession rate was relatively low. At that time the number of children had a statistically significant and positive impact on the inter-generational succession (the likelihood of it increased, *ceteris paribus*, by 15 per cent for each additional child). The succession of agricultural holdings was linked with the age of the farmer. The older he/she was, the higher was the likelihood of inter-generational and intra-generational succession. For a farm a one-year increase in manager's age raised the probability of this type of transfer, *ceteris paribus*, from 9 to 12 per cent and from 3 to 4 per cent respectively. Another statistically significant determinant of inter-generational farm succession was the sex of the manager. A statistically significant impact of this factor, however, was observed only in the first analysed period. At that time, taking over the agricultural holding by a younger person from a female manager happened relatively often. For a female farm manager, the likelihood of inter-generational was found to be significantly higher, namely*, ceteris paribus*, by 38 per cent.

The changes in the surveyed group of farmers had also a regional aspect. The situation of agricultural holdings in a specific part of the country either fostered or hindered their family transfers. The increased and statistically positive likelihood of inter-generational succession concerned the South-Eastern macro-region but only in the years of high rate of family transfers (Table 4). The location of farms in rural areas of that area increased the likelihood of this process, *ceteris paribus*, by 42 per cent. According to statistical analysis for the succession process the distance from the farm to urban areas was also of importance. The relatively longer spatial distance of farms to towns positively affected

[9] According to IERiGŻ-PIB study methodology, farm liquidation takes place when a farming family exits from agriculture through disposing of the agricultural land by selling or renting it outside the immediate family. In other words, farm liquidation means that household changes its socio-economic status from farming to non-farming. Two main reasons for such shifts are the abandonment of farming and taking-up non-agricultural activities by the rural population, and discontinuation of production upon retirement (Sikorska and Chmieliński, 2007).

Table 2: The rate of farm succession and liquidation in Poland, 2000-2011 (per cent).

Period 1 (2000-2005)		Period 2 (2005-2011)	
Succession rate – total	15.2	Succession rate – total	6.5
Inter-generational	12.8	Inter-generational	4.7
Intra-generational	2.1	Intra-generational	1.6
Reverse inter-generational	0.3	Reverse inter-generational	0.2
Farm liquidation rate	9.7	Farm liquidation rate	13.6

The percentages were calculated from 2000 for period 1 and 2005 for period 2
Data source: IERiGŻ-PIB surveys 2000, 2005, 2011

Table 3: The statistical influence of endogenous determinants of farm succession in Poland, 2000-2011.

Period 1 (2000-2005)		Period 2 (2005-2011)	
Type of succession	**Influence**	**Type of succession**	**Influence**
Inter-generational		Inter-generational	
Farmer's age	+	Farmer's age	+
Farmer's sex	+	Type of family	-
Type of family	-	Number of children	+
SE macro-region	+	SE macro-region	-
Distance to town	+	CW macro-region	-
Size of farm	+	N macro-region	-
Contract production	+	SW macro-region	-
Intra-generational		Intra-generational	
Farmer's age	+	Farmer's age	+
Distance to town	+	Farmer's education	-
		SE macro-region	-
		Credit	-
Reverse inter-generational		Reverse inter-generational	
Farmer's age	-	Number of children	-

Source: own elaboration based on logit models (MNL) of farm succession (see Tables 4 and 5) and the data from IERiGŻ-PIB surveys 2000, 2005, 2011

Table 4: Parameters of the multi-nominal logit model describing the factors statistically influencing the probability of farm succession in Poland in 2000-2005.

Variable	Coef-ficient	Std. error	T stat	Signif-icance	Odds ratio
Determinants of inter-generational succession					
Characteristics of farm manager					
Age	0.116	0.006	20.376	0.000	12.3
Sex (women)	0.320	0.146	2.196	0.028	37.8
Characteristics of farming family					
Type of family (single household)	-1.949	0.293	-6.649	0.000	-85.8
Characteristics of farm					
SE macro-region	0.349	0.139	2.516	0.012	41.8
Distance to nearest town	0.043	0.007	5.994	0.000	4.4
Size of farm	0.018	0.008	2.223	0.026	1.8
Contract sales of commercial production	0.449	0.140	3.199	0.001	56.7
Constant	-9.182	0.430	-21.371	0.000	-100.0
Determinants of intra-generational succession					
Characteristics of farm manager					
Age	0.035	0.010	3.432	0.001	3.6
Characteristics of farm					
Distance to nearest town	0.028	0.015	1,919	0.055	2.8
Constant	-5.887	0.711	-8.281	0.000	-99.7
Determinants of reverse inter-generational succession					
Characteristics of farm manager					
Age	-0.107	0.036	-2.996	0.003	-10.2
Constant	1.836	1.841	-0.997	0.319	-84.1

Source: own calculations

Table 5: Parameters of the multi-nominal logit model describing the factors statistically influencing the probability of farm succession in Poland in 2005-2011.

Variable	Coef-ficient	Std. error	T stat	Signif-icance	Odds ratio
Determinants of inter-generational succession					
Characteristics of farm manager					
Age	0.089	0.008	10.869	0.000	9.3
Characteristics of farming family					
Number of children	0.141	0.062	2.282	0.022	15.1
Type of family (single household)	-2.758	0.742	-3.717	0.000	-93.7
Characteristics of farm					
SE macro-region	-0.544	0.212	-2.571	0.010	-42.0
CW macro-region	-1.697	0.449	-3.782	0.000	-81.7
N macro-region	-1.005	0.446	-2.246	0.024	-63.3
SW macro-region	-0.784	0.348	-2.252	0.024	-54.4
Constant	-4.745	0.802	-5.918	0.000	-99.1
Determinants of intra-generational succession					
Characteristics of farm manager					
Age	0.034	0.011	2.956	0.003	3.4
Agricultural education	-1.064	0.450	-2.363	0.018	-65.5
Characteristics of farm					
Agricultural credit	-0.757	0.366	-2.070	0.038	-53.1
Constant	-4.745	0.802	-5.918	0.000	-99.1
Determinants of reverse inter-generational succession					
Characteristics of farm manager					
Number of children	-1.518	0.762	-1.991	0.046	-78.1
Constant	-4.745	0.802	-5.919	0.000	93.3

Source: own calculations

the inter-generational succession (a 1 km increase in distance increased the likelihood of succession, *ceteris paribus*, by 4 and 3 per cent respectively). In turn, when the farm transfers took place on a limited scale, the location of farms was statistically significant in most macro-regions, except the Central-Eastern macro-region, and hampered those processes. To the relatively greatest extent, this applied to the Central-Western macro-region. The location of the agricultural holding in this area reduced the probability of the inter-generational farm succession, *ceteris paribus*, by 82 per cent (Table 5).

According to IERiGŻ-PIB data, farm succession in Poland was primarily determined by the socio-demographic characteristics of farming families and factors concerning location of agricultural holdings. However, in both analysed periods, the impact of micro-economic determinants on the described phenomenon was noted. In the first period it was positive. The probability of inter-generational family transfer was higher for farms with commercial agricultural production sold under contracting agreements (*ceteris paribus*, by 57 per cent), as well as for agricultural holdings with the greater area of agricultural land (a 1 ha increase in the area increased the likelihood of succession, *ceteris paribus*, by 2 per cent). On the other hand, in the second period the impact on succession of economic factors was negative. It referred only to the intra-generational transfer of farms with agricultural credit (a decrease in the chances of succession, *ceteris paribus*, by 53 per cent) and the manager with completed agricultural education (a decrease in the likelihood of transfer, *ceteris paribus*, by 66 per cent).

Discussion

In the first analysed period the succession rate was particularly high and covered 15 per cent of all surveyed agricultural holdings. This high succession rate resulted from the situation in the overall economy as well as future considerable changes agricultural policy. The economic downturn along with the labour market imbalances translated into the instability of the living conditions of the farming population (Kaliński, 2009). That context contributed to the retention in families of the production assets (i.e. to keeping the agricultural land), even when those assets did not constitute a significant source of income. Secondly, the high rate of succession was an effect of preparation for EU accession. At that time many farming families resolved formal issues concerning land ownership, especially in the areas characterised by agrarian fragmentation and semi-subsistence farming (south-eastern part of the country) (Sikorska, 2005). However, the importance of policy context for farm transfers indicated that before Poland's accession to the EU and in the first years of membership the successions applied to many agricultural holdings regardless of their size and function. The upcoming transformations in the agri-food sector related to the implementation of the CAP resulted in the situation that farming families were relatively more willing to transfer the property rather than to sell it.

The change in economic conditions affecting the scale and direction of the transfer of agricultural holdings took place after Poland's accession to the EU (the second analysed period). The CAP instruments stabilised the situation in the agricultural markets and allowed investments to be implemented on a large scale (Czyżewski and Matuszczak, 2011). The demand for agricultural land increased as well, especially on the part of market-oriented farms, but also of non-agricultural enterprises (infrastructure development, urbanisation of villages). As a consequence, the succession frequency decreased substantially to 7 per cent of the total surveyed agricultural holdings. This level of farm succession was determined by the increased rate of market (non-familial) transactions of purchasing and selling of agricultural holdings which had been postponed due to relatively low land prices in the pre-accession period (Sikorska, 2012). As a result, in period 2 many families decided to sell their farms and the level of farm liquidation was relatively high, covering 14 per cent of the total sample.

The research results presented here show that the economic and policy context translated into the situation at the farming family level. Nevertheless, the succession of agricultural holdings in Poland was strongly affected by socio-demographic determinants that indicate the importance of the family life cycle, as well as the significance of the household's composition and size in this process. As was shown by Kimhi and Lopez (1999) and Glauben *et al*. (2004b), the likelihood of succession increased with the age of the farmer. Reaching the retirement age or an age close to it prompted a decision on transferring or selling the production assets. The presented analysis showed that succession of agricultural holding was possible when there are other persons to take over a farm in the household. It refers to the younger generation especially. However, it should be emphasised that in

some cases the number of persons in the household, particularly children, limited the chances of succession (Burton and Walford, 2005). This was especially true when the subjects of the transfer are usually big and market-oriented farms. The potential successors of such entities often compete for taking over the property. Regardless of the competition for the rights to the patrimony, having children makes it necessary to choose the right person to run agricultural production, which may be very difficult for the managers. In turn, in Poland, where the vast majority of farms are very small and often non-market oriented, transfers often take place late, when members of the younger generation have other gainful employment (they work mainly outside the farm before succession) and take over the holding to keep its ownership in the family. In this regard, the transfer patterns observed in the surveyed group fit the historically embedded and dominant succession model, reflected *inter alia* in the inter-generational transfer of the agricultural production assets in multi-person families.

It follows from the research results that the succession of agricultural holdings also determined the micro-economic determinants. However, their impact became not as visible as in other countries (Gasson and Errington, 2003; Mishra *et al*., 2004; Calus *et al*., 2008) and demonstrated at the time of important institutional and market changes related to the preparation for EU accession and economic instability (period 1). In Poland, owing to the possibilities of developing the agricultural activity, as well as prospects of receiving satisfactory remuneration, the tendency to take over medium and large size farms within a family was high at that time. Nevertheless, this situation applied to a small proportion of farming families running professional agricultural businesses. From the model analyses reported here it is evident that the chances of farm transfer to the young generation of successors increased when the production assets covered a significant area of land and contacts with agricultural market were intense and formalised in the legal contracts. In period 2 the impact on succession of two determinants was observed but it was negative and concerned only, occurred relatively rarely, intra-generational transfers.

The analysis also confirmed the importance of the location in a specific macro-region of the country on the probability of family succession of agricultural holdings. Relatively the highest rate of successions was observed in the eastern part of the country. In the first analysed period it referred the South-Eastern macro-region and covered 19 per cent of agricultural holdings located in that area. The high rate of succession there was associated with resolving the legal issues concerning the land use and ownership before Poland's accession to the EU. Regardless of this process, the practice of transferring the patrimony within the close family members was strongly rooted in the tradition of that macro-region (Sikorska, 2005). Many farms located in the south-eastern part of the country played residential and lifestyle roles and there was a strong tradition of property division between all children. Moreover, a number of non-economic benefits linked with the farm ownership made the farming families there rarely decide on its sale. On the other hand, as was mentioned earlier, in period 2 the scale of successions decreased considerably, even in south-eastern part of the country. This tendency was exemplified by the negative influence of location in almost all macro-regions on succession at the micro-level in period 2 (except for the Central-Eastern macro-region, where the succession rate in period 2 was relatively the highest and partly resulted from the imbalanced age structure of farmers from that area).

Apart from inter-generational changes in agricultural sector, the paper also considered two other types of family farm successions: intra-generational and reverse inter-generational. These transfers were observed in the surveyed sample, although only rarely. The former usually concerned transfers between spouses or partners and referred to the situation of one person's retirement or unexpected family events (such as migration, death, illness or divorce). The cases of reverse inter-generational were also very rare. They occurred in households consisting of a small number of people, where there were no successors from the younger generation. From the research it is evident than the factors limiting the chance of the reverse inter-generational succession ware the advanced age of the agricultural holding manager as well as the number of children in the household.

When considering the pace and determinants of farm succession in Poland it should be noted that this process has contributed to the balanced age of farmers as well as to the preservation of the hitherto rural settlement network so far. Nonetheless, the high rate of transfers of small and non-market-oriented entities within families has limited land concentration. Therefore, the policy instruments aiming at generational change in the sector should be revised in favour of tools that encourage some farmers to sell their agricultural property outside of the family.

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Lina BJERKE*

Knowledge in agriculture: a micro data assessment of the role of internal and external knowledge in farm productivity in Sweden

This study examines the impact of internal and external knowledge on firm productivity in the Swedish agricultural sector. It combines theories from regional economics about the geographical aspects of knowledge with traditional theories on the role of knowledge in productivity in agriculture. The study is a firm-level analysis using an unbalanced panel between the years 2002 and 2011 in Sweden. The results show that these firms are positively affected by employees with formal education related to the sector. Higher knowledge levels have a greater impact than lower levels. External knowledge, such as localised spillovers, is also important, but the results on this factor are more ambiguous.

Keywords: agriculture, competitiveness, productivity, accessibility

* Jönköping International Business School and the Swedish Board of Agriculture, Box 1026 551 11, Jönköping, Sweden. lina.bjerke@ju.se; http://orcid.org/0000-0002-1221-1054

Introduction

Knowledge is acknowledged as the most valuable resource for creating long-term competitiveness (Caloghirou *et al*., 2004). Although the extent to which low levels of knowledge are responsible for low growth and low innovativeness in the agricultural sector is not yet fully established, the European Commission heavily emphasises investments in 'knowledge generating assets' and considers these to be key drivers of future productivity growth (EC, 2008).

Since the 1970s, farms in Sweden have decreased in number, increased in size and, consequently, have often increased in output. The number of farms decreased by 6 per cent from 2005 to 2010. This is a smaller decrease than in comparable countries, but the number of farms larger than 100 acres has increased dramatically in Sweden, while aggregate production has remained stable (Manevska-Tasevska and Rabinowicz, 2015). The reason for this could be, for example, restrictions in land access, infrastructure, market access and type of labour supply.

While the Swedish agricultural sector is therefore no exception with respect to low growth, information on the factors that separate high- and low-performing firms is, to a large extent, still missing (Latruffe *et al*., 2008). Variations in physical production conditions cannot describe the whole story since differences are found in the same geographical area. This paper aims to identify the role of knowledge within firm control, i.e. *internal knowledge,* and knowledge outside firm control, i.e. *external knowledge*, in farm competitiveness, which is measured as total factor productivity (TFP). It combines the theoretical framework from regional economics on geographical knowledge spillovers with more traditional theories on agricultural productivity. By doing so, this study differentiates the concept of knowledge in agriculture by looking at internal knowledge and the impact of the knowledge milieu, and this is the main contribution of the paper.

All individuals have a number of characteristics, such as formal education, training and experiences that, in sum, is their accumulated human capital (Becker, 1962; Andersson and Beckmann, 2009). Human capital is widely accepted as an important part of productivity. In agriculture, such a positive effect of knowledge has grown over time as it has evolved from a traditional to a technical- and capital-intensive sector. The technical progress and rapid shifts in production techniques now require a type of knowledge that is different from that required 30 years ago. This not only means a higher level of knowledge but also a good ability to absorb new knowledge from external sources. Agglomeration, knowledge spillovers, regional specialisation and regional diversification characterise the regional milieu and can be important for firms' competitiveness. To the author's knowledge, no previous study has evaluated the Swedish agricultural sector from this perspective.

Returns to internal knowledge

Within firms, human capital can be referred to as *internal knowledge*. Human capital gives people the cognitive skills with which to interpret information and adapt to external knowledge, skills which are highly important in times of rapid internationalisation and technical development (Posner, 1961; Vernon, 1966). Human capital affects productivity at all levels of the economy and all types of industries, but 'labour quality' is often more important than magnitude (Griliches, 1957; Blundell *et al*., 1999; Fox and Smeets, 2011). Improved technology creates situations in which low-skilled labour is substituted for high-skilled labour. In the short term, all sectors compete for the same pool of highly skilled labour, and labour is a slowly adjusted factor of production. Thus, all industries need to be attractive alternatives with a sufficiently high rate of return on education. This is a challenge for industries with large fluctuations and low returns on education. The risk may become too high to engage in higher education related to these types of industries.

Agriculture has traditionally been a sector in which experience is more valuable than formal schooling, but technological progress has increased industry returns on schooling substantially (Becker, 1993; Huffman, 2001). Primarily, education becomes more significant when management requires a deeper and wider understanding of technology and business (Huffman, 2001). In the Swedish agricultural sector, approximately 19 per cent of workers have a postgraduate education and 9 per cent have a university degree. These figures are similar to those in the food

processing industry but only half of those for all types of manufacturing. Makki *et al*. (1999) show that United States farm operators with higher education positively affect productivity. The effect of education is primarily derived from a higher absorptive capacity and better adaptability to new conditions (e.g. leadership, strategies and market knowledge). One additional year of education increases farm productivity by 30 to 60 per cent. Furtan and Sauer (2008) obtained similar results when they showed that education has a significant effect on value added in the Danish food industry.

External knowledge

The surrounding milieu is an essential part of the picture when explaining a firm's accessible knowledge. In a dynamic economy with competition at the local, regional and global scales, firms must continually obtain new knowledge to stay competitive. However, most firms are small actors in large markets and are unable to manage all parts of renewal and firm development. Thus, firms combine internal knowledge with external knowledge, which creates opportunities for knowledge spillovers.

External knowledge can come from other individuals with related or unrelated knowledge or via specific business services (e.g. consultancies, economists, accountants, lawyers), and is found locally and from distant areas. Some types of knowledge sharing are very sensitive to geographical distance, which is explained in theories on agglomeration and New Economic Geography (Krugman, 1991). Knowledge is more complex than information and involves more friction when it is transferred. Space remains one type of friction that can still hinder very complex knowledge sharing across long distances (Polese and Shearmur, 2004; Boschma, 2005; Andersson and Beckmann, 2009). Being located near a supportive system and a network of potential collaborators facilitates knowledge generation, spread and absorption (Fischer and Fröhlich, 2001).

The rapid technological development and globalisation of agriculture speaks in favour of the more important role played by external knowledge. Despite this, agriculture has received little attention in theories of agglomeration. The presence of place-specific and immobile resources in agriculture is indeed a valid explanation for why it is different from some other industries. Nonetheless, technical advancements and increased dependence on cognitive skills makes it problematic to be located in the periphery, far from where high-end knowledge is created (Gruber and Soci, 2010).

External knowledge can also be obtained from international linkages (Bathelt *et al*., 2004; Shin *et al*., 2006). There is, for example, increasing evidence that firms combine local and global sources in their product renewal and innovation processes (Asheim and Isaksen, 2002; Simmie, 2003; Moodysson *et al*., 2008; Trippl, 2011). Extra-regional and global linkages take many forms, such as trade networks. Exports and imports are important sources of ideas for new products from all over the world, although this is often related to agglomeration (Jacobs, 1969; Bjerke *et al*., 2013).

Firm characteristics and their role in competitiveness

Firm age and firm size are factors that are shown *not* to perform uniformly over the firm life cycle (Jovanovic, 1982). On the one hand, as firms age, they rely on experience and act based on accumulated human capital (Cohen and Levinthal, 1990; Acemoglu *et al*., 2007). An older firm has also had more time to find a solid base on which to rely and thereby also has a lower failure rate. Thus, failure rates are higher earlier in firms' evolution (Jovanovic, 1982; Jovanovic and MacDonald, 1994). On the other hand, age can cause inertia, leading to lower innovativeness and creativity (Huergo and Jaumandreu, 2004).

In terms of firm size, the previous literature does not offer a coherent picture. Dahwan (2001) uses a panel of firms in the United States and shows that heterogeneity exists among industrial firms. Smaller firms have higher profit rates but lower survival probability. They also tend to be more productive, but their actions are also riskier. They encounter larger market uncertainties and capital constraints that force them to generate higher productivity as long as they survive in the market. International trade is also related to firm size: large firms are more likely to export than smaller firms (Mittelstaedt *et al*., 2003).

Related to agriculture, Latruffe *et al*. (2004) show that, irrespective of production type, size matters for efficiency in the Polish agricultural sector. A number of studies on agricultural firm size and firm performance have addressed this topic from a policy perspective, as well as the effect of technological progress and structural change. However, the vast majority of these studies exclude the matter of human capital and how firms are affected by different types of internal knowledge and localised knowledge spillovers.

Methodology

The data are an unbalanced panel of Swedish firms in the agriculture industry between 2002 and 2011 and are provided by Statistics Sweden. The data cover all firms and all employees in Sweden and include information on account data and detailed information on individuals. Individuals and firms can be linked together and located in a specific area, which means that it is possible to control for the surrounding milieu. Data are organised as an unbalanced panel with approximately 248,000 observations.

Total factor productivity (TFP) and estimated model

Productivity is a reliable measure of long-term competitiveness (EC, 2008; Latruffe, 2010). This paper adopts the standard procedure of a two-step TFP. Human capital is excluded in the first step, corresponding to previous studies. Islam (1995) shows that human capital affects TFP but cannot explain output. Similarly, Benhabib and Spiegel (1994) show that human capital does not enter the production function as an input but rather as an explanatory variable for the growth of TFP.

The model is restricted to constant returns to scale due to industry structure and data restrictions. Firstly, data cannot control for firm diversification or the value of arable land.[1] This poses a restriction on how to interpret capital but also on the relationship between labour and capital. Firms in the data are heterogeneous in terms of capital and relatively homogenous in terms of labour. However, the vast majority of firms has only *one* registered person in the firm (usually the owner). Therefore, some small firms are highly capital intensive. The industry shift towards fewer but larger Swedish agricultural firms with low profitability is not fully explained. Increasing return-to-scale economies may apply to the entire industry (or a within-industry group) rather than to individual firms. Sheng *et al*. (2015) use Australian broad acre firm data and find that higher productivity within larger firms is not a result of increasing returns to scale but rather constant or mildly decreasing returns. The larger firms achieve higher productivity through changes in technology rather than scale. Smaller firms tend to improve their productivity through the ability to access and absorb advanced technologies rather than growing in size.

While the sector is growing, it is profitable for it to absorb new technology. This allows increased production and reduced costs for the entire sector, while each firm encounters constant returns to scale and acts as a price taker, i.e. *external economies* of scale (Hallam, 1991). Thus, firms remain small in the global market, and one can use the mindset of a competitive equilibrium.

TFP is the average product of inputs, and the Cobb-Douglas production function with capital and labour as factors of production is as follows:

$$Y = AK^{\alpha}L^{\beta}, \text{where } \alpha+\beta = 1 \textit{ for firm } i \tag{1}$$

where Y is the firm output, K is the total stock of physical capital, L is the labour forces measured as the number of workers in the firms. A is subsequently the TFP.

Dividing equation (1) by L gives:

$$y = Ak^{\alpha}L^{\beta}, \textit{where } \beta = (1-\alpha) \tag{2}$$

where y is the output (value added) per worker and k is the per worker capital. Taking the natural logarithm, equation (3) is obtained:

$$\hat{y} = \ln TFP = \ln y = \ln A + \alpha \ln k + \beta \ln L \tag{3}$$

The elasticity of output with respect to the within-firm physical capital is 0.4 and is strongly significant. With a constant return to scale, the elasticity of the output with respect to labour is 0.6.

Subsequently, $\hat{y}$ determines the effect of internal and external knowledge on total factor productivity, TFP. The estimated model will then be as follows:

$$\ln TFP_{i,t} = a_1 + [Firm_{i,t}]' a_2 + [Internal\ Knowledge_{i,t}]' a_3 + [External\ Knowledge_{i,t}]' a_4 + \varepsilon_{i,t}$$

where t=2002,… …,2011. The model consists of three vectors of variables: one related to firm characteristics, one related to internal knowledge and one related to external knowledge variables. The following section gives more detailed descriptions of these variables.

Variables and descriptives

Measuring knowledge in the surrounding milieu has its origin in the knowledge production function proposed by Griliches (1979). Knowledge is partly distance sensitive, which means that knowledge spillovers are affected by distance but also by types and magnitudes and can, in total, be summarised as knowledge accessibility. Weibull (1976) developed a measure of this gravity potential problem, which is further developed and applied by, for example, Johansson and co-workers (Johansson *et al*., 2002, 2003).

Sweden has 290 municipalities, and the accessibility of municipality i to itself and the $n-1$ surrounding municipalities is defined as the sum of the internal accessibility to a given opportunity D and its accessibility to the same opportunity in other municipalities:

$$A_i^D = D_1 f(c_{i1}) + \ldots + D_i f(c_{ii}) + \ldots + D_n f(c_{in}) \tag{4}$$

A_i^D is the sum of the accessibility of municipality i, and D_i is the amount of opportunity for face-to-face contact. $f(c)$ is the distance decay function that determines how the accessibility value is related to the costs of reaching this specific knowledge. An approximation of this is an exponential function, such as:

$$f(c_{ij}) = \exp\{-\lambda t_{ij}\} \tag{5}$$

where λ is a time distance parameter and t_{ij} is the travel time distance between location i and location j. Consequently, total accessibility is a function of the sums of internal and external accessibility, where the potential opportunities are negatively related to distance:

$$A_i^D = \sum D_j \exp\{-\lambda t_{ij}\} \tag{6}$$

The independent variables are described in Table 1, beginning with the variables related to the firm characteristics and internal knowledge. Data contain information on age but only if the firm was established after 1986. To control for age bias, a dummy variable for firms with an establishment year of 1986 is used. Data also allow us to control for firm size in terms of net sales and trade activity and also whether the firm engages in trade (export and/or imports).

Measures of internal knowledge are divided into those of a general character and those directly related to agriculture. To control for human capital accumulated through ways other than education, experience in other unrelated industries and in the agricultural sector are also added.

The third section of Table 1 contains all accessibility variables, i.e. external knowledge. Firstly, these are divided into types of knowledge, such as access to employees with related and unrelated college or university degrees. Variables aiming to capture the effect of larger access to support busi-

[1] Data on land are available at the municipal level. This has been controlled for in all estimations with robust results.

Table 1: Variables, their descriptions and motivations.

Variable name	Description
Firm characteristics	
$Firm\ age_{i,t}$	Age at year *t*
$Old_{i,t}$	1: if registered as established in 1986; 0: otherwise
$Firm\ size_{i,t}$	Net sales at year *t*
$Trade_{i,t}$	1: if exporter and/or importer; 0: otherwise
Internal knowledge	
$GenColleg_{i,t}$	Share of employees in firm *i* with college degrees (except those with *AgriColleg*)
$AgriColleg_{i,t}$	Share of employees in firm *i* with agricultural college education*
$GenHigh_{i,t}$	Share of employees in firm *i* with ≥3 years of university education (except those with *AgrHigh*)
$AgrHigh_{i,t}$	Share of employees in firm *i* with ≥3 years of university, agricultural-related, education
$BAHigh_{i,t}$	Share of employees in firm *i* with university degrees in business and administration**
$ShareAccount_{i,t}$	Share of employees with main work tasks within accounting and/or marketing
$AgriExpert_{i,t}$	Sum of employee years (last ten years) in agriculture
$(AgriExpert_{i,t})^2$	
$GenExpert_{i,t}$	Sum of employee years (last ten years) in other industries
$(GenExpert_{i,t})^2$	
External knowledge	
$TotAccAgriColleg_{i,t}$	Total accessibility to individuals with college education in agriculture
$TotAccHighAgri_{i,t}$	Total accessibility to individuals with higher education in agriculture
$LocalAccAgr_{i,t}$	Local accessibility to employees with an agricultural education employed in business support firms****
$RegAccExpAgr_{i,t}$	Intra-regional accessibility with an agricultural education employed in business support firms****
$ExtAccExpAgr_{i,t}$	Extra-regional accessibility with an agricultural education employed in business support firms****
$TotAccKIBS_{i,t}$	Total accessibility to KIBS (NACE 72-74)

* Codes 620z-629z according to Sun2000Inr; ** codes 340a-349z according to Sun-2000Inr; *** occupations are classified according to the Swedish standard for occupational classification, SSYK; **** Employees with education within 340a-349z according to Sun2000Inr classification
Source: own composition

nesses also exist. Access to agricultural support is measured as the number of people with formal education in agriculture who work in business support. Access to KIBS is correspondingly all employees in knowledge intensive business services (KIBS).

Figure 1 presents the localisation of employees in Sweden, divided into the 290 existing municipalities. Figure 1a presents each municipality's share of employees with a college degree related to agriculture, and these are relatively well distributed across Sweden. Figure 1b shows the share of employees with higher education (at least three years of university education) within agriculture. These are more clustered in space, as is also the case for all other individuals with higher education (Figure 1c).

The third section of Table 1 presents variables related to external knowledge. Knowledge accessibility is differentiated into local, inter-regional, and extra-regional, as described above (this can also be measured as total accessibility when all three are added together). Owing to the tendency towards knowledge clustering in space irrespective of type, some accessibility variables capture the effect of population density. Knowledge intensive businesses in particular tend to be distance sensitive and are located in dense areas; they could therefore have difficulties reaching more peripheral areas. This also implies that accessibility to KIBS and accessibility to agricultural support have a bivariate correlation of 0.83.[2]

Results

The results are displayed in Tables 2 and 3; the latter focuses on the effect of external knowledge and thoroughly disentangles the accessibility measure.

[2] Bivariate correlations can be provided by the author upon request.

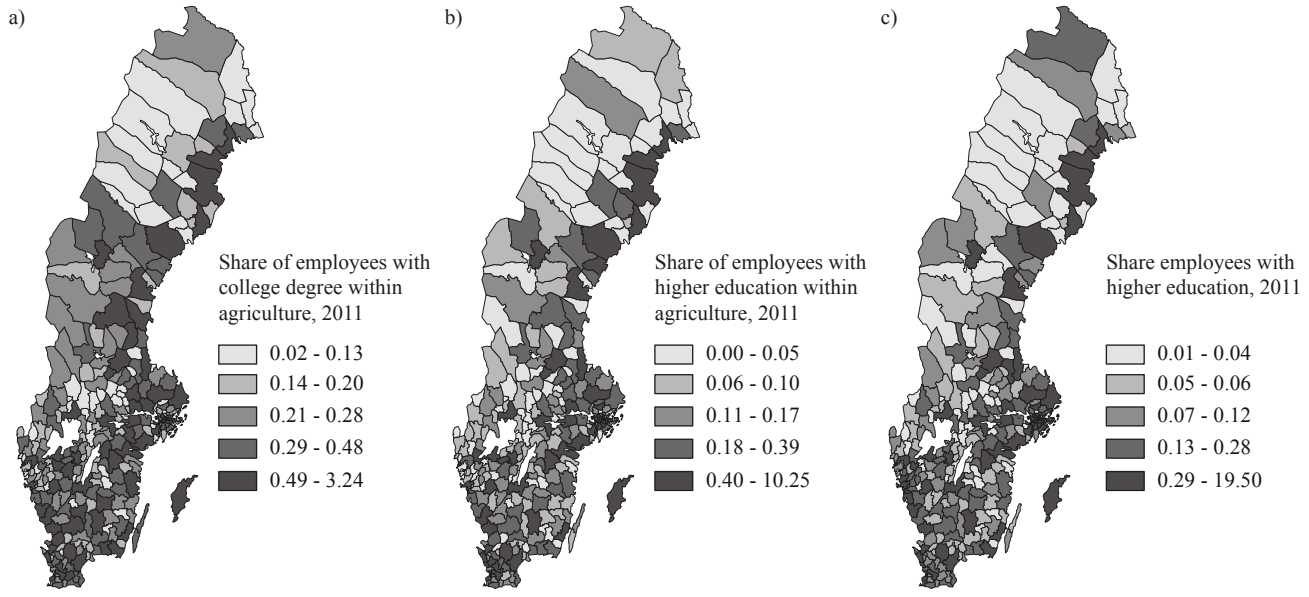

Figure 1: Municipality's share of Sweden's employees with (a) agricultural college degree; (b) agricultural university degree; and (c) all with university degree.
Source: own composition

Table 2: Unbalanced panel regression results, fixed effect.

Variable name	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
$Firm\ age_{i,t}$		0.004***	0.004***	0.004***	0.004***	0.004***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$(Firm\ age_{i,t})^2$		-9.17e-5***	-9.16e-5***	-9.20e-5***	-9.17e-5***	-9.09e-5***
		(1.78e-5)	(1.78e-5)	(1.78e-5)	(1.78e-5)	(1.78e-5)
$Firm\ size_{i,t}$		-0.055***	-0.055***	-0.055***	-0.055***	-0.055***
		(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
$(Firm\ size_{i,t})^2$		1.15e-4***	1.15e-4***	1.15e-4***	1.15e-4***	1.15e-4***
		(2.51e-6)	(2.51e-6)	(2.51e-6)	(2.51e-6)	(2.51e-6)
$Trade_{i,t}$		0.036***	0.036***	0.036***	0.036***	0.036***
		(0.008)	(0.008)	(0.008)	(0.008)	(0.008)
$Old_{i,t}$		-0.013**	-0.014**	-0.013*	-0.013**	-0.014**
		(0.007)	(0.007)	(0.007)	(0.007)	(0.007)
$GenColleg_{i,t}$	-0.022***	-0.013***	-0.013***	-0.013***	-0.013***	-0.013***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$AgriColleg_{i,t}$	0.032***	0.018***	0.018***	0.018***	0.018***	0.018***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)	(0.005)
$GenHigh_{i,t}$	-0.021*	-0.013*	-0.013*	-0.013*	-0.013*	-0.012*
	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)	(0.012)
$AgrHigh_{i,t}$	0.081***	0.060***	0.060***	0.060***	0.060***	0.060***
	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
$BAHigh_{i,t}$	4.29e-4					
	(0.010)					
$ShareAccount_{i,t}$	9.86e-6***	5.75e-6***	6.15e-6***	5.22e-6***	5.79e-6***	7.69e-6***
	(1.27e-6)	(1.26e-6)	(1.26e-6)	(1.35e-6)	(1.29e-6)	(1.44e-6)
$AgriExpert_{i,t}$	-0.010***	-0.006***	-0.006***	-0.006***	-0.006***	-0.006***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
$(AgriExpert_{i,t})^2$	0.003***	0.002***	0.002***	0.002***	0.002***	0.002***
	(9.56e-5)	(9.65e-5)	(9.65e-5)	(9.65e-5)	(9.65e-5)	(9.65e-5)
$GenExpert_{i,t}$	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***	-0.008***
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.00117)
$(GenExpert_{i,t})^2$	-7.60e-4***	-7.74e-4***	-7.76e-4***	-7.72e-4***	-7.74e-4***	-7.98e-4***
	(8.87e-5)	(8.77e-5)	(8.77e-5)	(8.77e-5)	(8.78e-5)	(8.82e-5)
$TotAccAgriColleg_{i,t}$			-1.17e-5***			
			(4.18e-6)			
$TotAccAgriHigh_{i,t}$				4.12e-5***		
				(3.99e-5)		
$TotAccAgrSup_{i,t}$					-7.86e-5***	
					(5.25e-5)	
$TotAccKIBS_{i,t}$						-5.13e-6***
						(1.84e-6)
N	248,148	248,148	248,148	248,148	248,148	248,148
R^2 within	0.08	0.08	0.08	0.08	0.08	0.08
R^2 between	0.02	0.02	0.02	0.02	0.02	0.02
R^2 overall	0.01	0.01	0.01	0.01	0.01	0.02

Source: own calculations

Internal knowledge

Model 1 focuses on internal knowledge. A larger share of employees with 'non-related' college degrees has a negative effect on productivity. A larger share of employees with agricultural-related college degrees affects productivity positively. These two types of employees may have a crowding-out effect on each other if they are substitutes, but they may also be two complementary labour inputs. The bivariate correlation between these two is negative but small (-0.3), indicating that they are substitutes for each other, but not with a predominant crowding-out effect.

Higher education variables show similar effects in which 'related' education positively affects productivity. The size of this is slightly larger than that of agricultural college degree. The effect of formal education within business and administration has no significant effect in this model and is excluded in the subsequent analysis. Having a larger share of employees within marketing and/or accounting has a positive effect, and this is robust with only minor variations.

The average years of experience per employee are initially negative when the experience is within other agricultural firms, but the effect changes direction relatively quickly (after one and a half years). Thus, related experience can be considered as positive for productivity, although it should be emphasised that this, to some extent, also captures the age of the employees. However, the effect of experience does not behave the same when measured as average years employed *outside* the sector. In this case, the effect on productivity is continuously negative. As for education, these two types of employees can affect each other negatively with a slight crowding-out effect. They are tested separately but are robust.

What clearly emerges from Table 2 is that knowledge acquired from formal education is closely related to agriculture and is important for productivity. Moreover, higher education appears to have a slightly larger effect than hiring more employees with 'only' an agricultural college degree. It is also important to emphasise that employees with college degrees are more evenly distributed geographically, and higher knowledge is more clustered in space. This is true for all types of higher knowledge, and one can possibly therefore assume that the marginal effect of higher knowledge varies in space.

Firm characteristics

Firm age and size are robust across all models. Firm age is positive, but the squared version is negative with the interpretation that productivity increases as the firm ages. This effect becomes negative when the firm has existed for slightly more than 20 years. This result is strengthened by the dummy controlling for the older firms, which is negative across all models. Firm size is, on the other hand, initially negative and thereafter positive. It is plausible to assume an effect of the appearance of the product life cycle in which the firms need to become a certain size to dedicate resources to *increase* productivity. Whether an agricultural firm engages in trade is highly robust and positive across all models.

One part of external knowledge is international trade, and the results show that firms that engage in trade have higher productivity. Trade offers a channel of knowledge and facilitates awareness of, for example, international production techniques, processes, services and logistic solutions. The effect of trade should not be neglected; even though further research is needed with regard to agriculture. This sector is exposed to greater competition from abroad, which increases the pressure to increase productivity through innovation and renewal. This is a way to maintain a present market position or even attain a new position in the market.

External knowledge

Firms have few possibilities for influencing external knowledge except changing location, which per se is impossible for production that is based on immobile resources. Given the potential for the endogeneity of these external knowledge variables, the findings should be interpreted with care even though the fixed effect should remedy the issue substantially.

Table 1 presents the external knowledge variables as the

Table 3: Unbalanced panel regression results controlling for external knowledge, fixed effect.

Variable name	Model 7	Model 8	Model 9	Model 10	Model 11
Controlling for firm variables as in Table 2, model 2. Results are robust.					
$LocAccAgriColleg_{i,t}$	1.23e^{-5}*** (8.71e^{-6})				
$RegAccAgriColleg_{i,t}$	-2.12e^{-5}*** (4.54e^{-6})				
$ExtAccAgriColleg_{i,t}$	1.18e^{-4}** (1.94e^{-5})				
$LocAccAgriHigh_{i,t}$		-2.87e^{-4}*** (5.24e^{-5})			
$RegAccAgriHigh_{i,t}$		4.68e^{-5}*** (5.60e^{-5})			
$ExtAccAgriHigh_{i,t}$		0.006*** (0.003)			
$LocAccGenHigh_{i,t}$			-2.84e^{-6}*** (4.06e^{-7})		
$RegAccGenHigh_{i,t}$			5.51e^{-7}*** (3.48e^{-7})		
$ExtAccGenHigh_{i,t}$			1.91e^{-5}*** (2.28e^{-6})		
$LocAccAgrSup_{i,t}$				-0.002*** (0.001)	
$RegAccAgrSup_{i,t}$				0.002* (0.001)	
$ExtAccAgrSup_{i,t}$				0.017*** (0.004)	
$LocAccKIBS_{i,t}$					-2.16e^{-5}*** (3.20e^{-6})
$RegAccKIBS_{i,t}$					2.12e^{-7}*** (2.51e^{-6})
$ExtAccKIBS_{i,t}$					1.27e^{-4}*** (1.57e^{-5})
N	248,148	248,148	248,148	248,148	248,148
R^2 within	0.09	0.09	0.08	0.08	0.08
R^2 between	0.02	0.02	0.02	0.02	0.02
R^2 overall	0.02	0.02	0.01	0.02	0.02

Source: own calculations

sums of all three levels of accessibility. Accessibility presented in this way can also describe other characteristics of a region (Figure 1). Models 3 and 4 control for total accessibility to employees with agricultural college degrees and agricultural university degrees. Access to employees with college degrees has a negative effect on productivity, while greater access to university agricultural knowledge is positive. Models 5 and 6 control for total accessibility to agricultural support businesses and knowledge-intensive business support services. As expected, these two have the same sign, which indicates that both cluster in space in a similar way. A dense location may be favourable, regardless of the location of clients, which often has the effect that headquarters tend to be located in larger cities. However, employees are assessed at their workplaces, which implies that the risk of underestimating employees 'out in the country' diminishes substantially.

External knowledge is further explored in Table 3. Models 7 to 11 control for accessibility in more detail, i.e. local, intra-regional and extra-regional accessibility.

Model 7 controls for the accessibility of employees with college degrees related to agriculture. In Table 2, this was negative when aggregated as total accessibility. In model 7, local accessibility is significantly positive for firm productivity. Intra-regional accessibility is, on the other hand, negative, while extra-regional access is positive. Again, one has to consider that these firms are highly dependent on place-specific resources, and this may be captured in these separated versions of accessibility. Being located close to a large pool of employees with agricultural college degrees is possibly also an effect of being located in a prosperous milieu for production. However, a local milieu with high access to employees with higher agricultural education is not prosperous, probably because that type of knowledge tends to cluster in places other than rural areas.

Model 8 isolates the effects of local, intra-regional and extra-regional access to higher agricultural knowledge. Total accessibility in Table 2 was positive, but the local accessibility is now negative. However, the intra- and extra-regional access is positive, which again may show location advantages. Being too distant from knowledge is disadvantageous, but being too close means not being near rural prosperous land. The similarity between the location of greater agricultural knowledge and the location of knowledge in general is further accentuated by model 9.

The remaining two models in Table 3 measure accessibility to agricultural business support and other knowledge-intensive business support services. In terms of the direction of effects, they turn out similarly with a negative local effect and positive regional effects. The effect of accessibility to agricultural business support is substantially greater than the effect of KIBS access.

All models have relatively low R^2 values. This is of minor concern in this analysis. Firstly, this is a study on human capital and its effect on productivity, not a study on the type of variables that affect TFP in total. A low R^2 does not mean that the effect is 0. Secondly, this is a panel data estimation with R^2 values, which should not be compared to those of time series. Thirdly, the analysis is a study of a population and not a sample.

Discussion

This study analyses the performance of Swedish agricultural firms between 2002 and 2011. The goal is to determine how different types of internal and external knowledge, conditional on firm characteristics, affect productivity. The way in which this study applies theories on return on education, knowledge agglomeration and knowledge spillovers is a somewhat novel perspective in agricultural economics. However, this approach is highly relevant in times in which agricultural labour is being substituted by capital, human capital and technology.

The paper primarily investigates the effect of formal education, both related and unrelated to agriculture, at the college level and at the university level. The analysis of internal knowledge is accompanied by variables on external knowledge, which represent knowledge accessibility. From the previous literature, one would expect that formal education has a positive effect on firm performance. The expected effect of external knowledge is not as straightforward to estimate in advance. Other producing industries can take advantage of co-locating with other firms that are more or less related. The case of agriculture is more difficult to predict since the industry is highly dependent on place-specific and immobile resources. However, at a time when technology and knowledge have become a principal part of agriculture and its competitiveness, knowledge in the surrounding milieu has become even more interesting to study.

The econometric analysis finds that formal education has a positive effect on productivity as long as the education is related to agriculture. Agricultural college and university education are both positive, but the latter has a slightly larger effect than the former. It appears to be profitable to hire an employee with higher formal education, even though the relatedness to agriculture is the most important factor. Although a larger share of other formal education has a negative effect, this should not be interpreted as the answer to how to balance the two types of employees within a firm. This should be further explored in future research.

The conclusion from this is that knowledge matters for the Swedish agricultural sector, just as it does for other sectors. Formal education is important and has a higher value added if it is related to the sector itself. This supports having well-established and high-quality structured educational programmes for the agricultural sector. However, this does not mean that other competences are insignificant, as shown in the positive effect of having high levels of access to business support, i.e. external knowledge.

External knowledge appears to be important, with the caveat that some locational advantages are difficult to separate from an otherwise prosperous knowledge milieu. Nevertheless, accessible knowledge is also advantageous for agriculture. Agriculture is an industry that is characterised by a well-established support system (agricultural consulting) in Sweden. The results show that access to these types of services matter, but it is again difficult to distinguish this effect from that of knowledge agglomeration and the tendency for knowledge intensive business services to be located in relatively dense urban areas. This type of 'urbanisation', in which knowledge is located far from its 'end consumer',

is an important policy message itself: knowledge demand fails to match knowledge supply. This is particularly true for agriculture, which has a predominantly rural location with immobile production. It is a dilemma if knowledge tends to cluster in dense areas while the agricultural industry has an increasing demand for this specific high-end knowledge. The inability to relocate affects industry attractiveness and competitiveness.

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BIRÓ Szabolcs*[1], HAMZA Eszter*[2] and RÁCZ Katalin*[3]

Economic and social importance of vertical and horizontal forms of agricultural cooperation in Hungary

In the development of a market economy, the ability to cooperate is a major factor determining the competitiveness of economic actors. With complex instruments intended to stimulate cooperation among the actors in farming, the agri-food chain, forestry and rural development, strengthening cooperation is a priority of the Common Agricultural Policy in the current European Union programming period. This paper evaluates the development of different forms of vertical and horizontal cooperation between actors in Hungarian agriculture in the period 2007-2013. Our definition of cooperation is based on a regular market relationship, and our analysis includes not only formal forms of horizontal and vertical cooperation but also the informal networks offering business benefits for producers. The main conclusion is that, owing to the continuing low level of horizontal cooperation in Hungary, high-level vertical integration ensures that producers can achieve a favourable negotiating position, and this in turn reduces the potential for the development of horizontal cooperation. Informal relationships, such as doing favours without charge, are not negligible ways of accessing resources, especially for small farms. A development path for agricultural cooperation in Hungary might be for actors to make collective investments in order to increase value-added and utilise economies of scale, and to organise themselves into alliances, associations, networks and clusters. Beyond the benefits originating from market concentration, these steps could stimulate the dissemination of expertise, improve efficiency and increase innovation capacities.

Keywords: integrators, Producer Groups, Producer Organisations, cooperatives, clusters, machinery rings

* Agrárgazdasági Kutató Intézet, Zsil utca 3-5, 1093 Budapest, Hungary. Corresponding author: biro.szabolcs@aki.gov.hu

Introduction

In market economies, one of the main success factors of competitiveness is the ability to cooperate (Csizmadia and Grosz, 2012). Strengthening cooperation is a major priority in the European Union's (EU) Common Agricultural Policy (CAP) in the period 2014-2020, so financial support has been extended to all "… cooperation, among different actors in the Union agriculture sector, forestry sector and food chain and other actors that contribute to achieving the objectives and priorities of rural development policy, including producer groups, cooperatives and interbranch organisations" (EC, 2013, p.516).

Essentially, there are two forms of cooperation in agriculture, vertical and horizontal, defined on the basis of the relationships between producers. Integrator companies (organisations registered according to Regulation no. 25/2004 of the Hungarian Ministry of Agriculture and Rural Development) constitute the main type of vertical integration in Hungary. Although they developed into their current form in the late 1960s, large processing companies (such as sugar factories, seed growers and tobacco manufacturers) existed before then, in conjunction with agricultural industrialisation. Through dissemination of modern technologies and organisation of industrial production, they played a significant role in the Hungarian agricultural boom that lasted until the mid-1980s (Enyedi and Rechnitzer, 1987). In the past two decades the integrator networks have gone through continuous change. In addition to the other participants, major domestic and international companies (such as Cargill, Glencore and Syngenta) have become market leaders in Hungary. While in the years following political and economic transition – in connection with the incomplete assets of farms – the integrators' main role was mainly input and equipment provision, storage, processing, and commercial and marketing activities, recently their financing, crediting and innovating functions have become important (Kemény, 2010). The economic importance of agricultural integrators is increased by the provision of inputs and services closely linked to farming processes, and by maintaining direct relationships with the processing and commercial sectors. This hierarchical relationship is based on a contract between the integrator and the producers (Juhász and Mohácsi, 1995).

Many forms of horizontal cooperation (i.e. cooperation between entities of similar size and position) can be found in Hungarian agriculture. The cooperation may be based on marketing and sales collaboration, a common product, or even joint production and storage capacities. The aim is to achieve a common competitive advantage based on economies of scale, or greater purchasing or bargaining power (Sáfrányné Gubik, 2008). Horizontal agricultural cooperation can be either formal or informal. The most common forms of formal horizontal cooperation in Hungary are cooperatives (a traditional form of formal agricultural cooperation registered by the National Tax and Customs Administration of Hungary, NTCA), Producer Groups (PGs), and Fruit and Vegetable (F&V) Producer Organisations (POs), while the informal ones include services provided without charge and machinery cooperatives (Szabó, 2011). In addition, integrator companies and clusters (the spatial concentration of competing enterprises, suppliers and servicing industries of a given fields of activity; Porter, 2000) operate as vertical cooperations covering a considerable part of entire product lines.

Since the 1990s, much research has been carried out in Hungary on the willingness of agricultural producers to cooperate and on the role of the producer organisations. For example, Juhász (1999) studied the F&V sector, Szabó (1999) analysed vertical cooperation and integration in the milk sector, Tóth (2000) looked at the agricultural cooperatives and Dorgai *et al.* (2005) assessed the agro-economic roles of POs and PGs. More recently, Dorgai *et al.* (2010) and Baranyai *et al*. (2013) have shown that, although the

[1] http://orcid.org/0000-0002-1029-0836
[2] http://orcid.org/0000-0002-6039-7084
[3] http://orcid.org/0000-0003-2286-4793

formal cooperation has increased since the political and economic transition after 1989, the willingness of farmers in Hungary to cooperate, with the exception of some traditionally well-organised sectors (F&V, wine and poultry), is at a low level. Tóthné Heim (2011) found that farmers in the South Transdanubian NUTS 2 region of Hungary have no particular interest in cooperation because of individual interests and high risk aversion. Takács and Baranyai (2010) showed that the willingness to cooperate is lowest among the smallest farms and the highest among medium-sized farms (those with an economic size of 4-8 European Size Units). Dudás and Juhász (2013) pointed out that formal cooperation mainly promotes the interests of the larger producers.

The benefits of cooperation have been widely documented. Wolek and Lopaciuk-Gonczaryk (2006) demonstrated the economic efficiency of informal cooperation. In contrast to the results of Takács and Baranyai (2010), they showed that informal cooperation is the 'capital of the poor', as in Poland it was the strongest among the smallest farms. Through cooperation, farmers could reduce their production costs. This horizontal cooperation is casual; the low incomes prevent the establishment of more developed forms. Horváth (2010) pointed out that among the forms of formal agricultural cooperation the economic role of the F&V POs was increasing. Lanz and Miroudot (2011) showed that besides the F&V POs the role of integrations representing high value-added was also increasing. Szabó (2011) reported that in recent decades a great number of favourable processes started but the horizontal connections of the producer cooperation are still very weak. Seres *et al.* (2011) showed that the development path of POs is not necessarily to involve more members, but rather to increase the sales ratio of the members, the integration of the product chain and the expansion of the PO's services.

This paper examines the development and the relative economic importance of vertical and horizontal cooperation in Hungary in the period 2007-2013. Through comparison of statistical data from different sources, a questionnaire and interviews, we compare the performance of the various cooperation models, identify benefits offered by cooperation over and above those that are already widely known, assess the main constraints to achieving the potential that is possible through cooperation, and evaluate the opportunities and the directions of improvements in cooperation in Hungarian agriculture. Further objectives are to answer the following general questions: what fundamental factors play a role in the development of cooperation, and what are the motivations of the actors and the key success factors and pitfalls? On this basis, the following research questions were formulated: (1) what is the role of the integrator companies in organising the cooperation in connection with the low-level producer relationships; (2) to what extent has the producers' network developed in Hungary since 2007, if at all; and (3) what kinds of developments can be expected in Hungary in the fields of agricultural cooperation.

Methodology

We adopted three approaches in this research. Firstly, official data sets were used to quantify the economic performance and the other main characteristics (e.g. the number of organisations and the size of their membership) of the dominant forms of cooperation with formal organisational characteristics in Hungarian agriculture (cooperatives, PGs, F&V POs and integrators) in the period 2007-2013. This was not a simple task as there is no single aggregated statistical database available which is of consolidated structure and upgraded regularly. In the database of the NTCA, only cooperations operating as agricultural cooperatives can be identified clearly; for the other organisational forms it was necessary to identify the formal organisational form on a case-by-case basis according to the organisational registrations. The Ministry of Agriculture maintains records about the PGs and F&V POs, and the County Offices of the Ministry of Agriculture keep records on the organisations registered as integrator companies. Data on clusters which applied for subsidies in the period 2007-2013 were extracted from the support database of the Hungarian National Development Agency.

Secondly, in 2013-2014 two institutes of the Hungarian Academy of Sciences, namely the Institute for Sociology of the Centre for Social Sciences, and the Centre for Economic and Regional Studies, jointly conducted a questionnaire survey of a representative sample of one thousand farmers selected on the basis of farm characteristics (for example, size and sector) and geographical location. The survey covered eight LAU 1 micro-regions of Hungary[4] and the base population consisted of natural and legal persons who received CAP direct payments in 2012 and farmed more than one hectare of land. From the results of this survey we analysed the willingness of farmers to cooperate, both formally and informally. The questionnaire included questions on in-kind and community use of land and machinery, from the aspect of formal cooperation on purchase of farm inputs, sale and services within the organisation and on the membership of organisations; while the questions on informal cooperation covered the categories of acquisition of information, discussions of problems and general confidence.

We tested for statistically significant correlations in the survey sample between some of the parameters of the farms and the farmers, farmers' attitudes to cooperation and different forms of cooperation. Pearson product-moment correlation was run using IBM® SPSS® Statistics 22 (IBM, Armonk, North Castle NY, USA). In instances where one of the variables (e.g. gender) was measured on a dichotomous scale, a point-biserial correlation was used to measure the strength and direction of the association that exists between the continuous variable and the dichotomous variable.[5]

Thirdly, the potential for the development of agricultural cooperation in Hungary was explored with the help of structured, in-depth, face-to-face interviews conducted in 2014 and 2015 with 19 leaders of agricultural organisations involved in formal cooperation activities. Interviewees were selected to be representative in terms of professional management, membership and the various sectors and organisational forms. We chose three clusters involved in agriculture

[4] Fehérgyarmati, Hajdúnánási, Marcali, Bóly-Mohácsi, Zalaszentgróti, Budakeszi-Tatabányai, Nagykőrösi and Gyöngyösi.

[5] See https://statistics.laerd.com/spss-tutorials/point-biserial-correlation-using-spss-statistics.php

and visited the representatives of six relevant professional organisations (four of the larger producer councils (F&V, milk, poultry and pig) and two bodies representing farmers' interests with large memberships). Further, on the basis of recommendations from the professional bodies we selected the managers of six successful organisations including PGs and F&V POs and four integrator companies. We asked the interviewees questions on their activities and on the operation of their organisation as well as on any new factors assisting or hampering the cooperation over and above those that are already widely known.

Results

Relative importance of vertical and horizontal agricultural cooperation

There are almost 1500 formal agricultural cooperations in Hungarian agriculture and their economic role is shown by the fact that their combined net revenue (generated mainly from sales of inputs and agricultural machinery, the processing and marketing of agricultural products, and associated services) in 2013 (HUF 2,065 billion) was comparable to the total output (the sales of farm products and the value of on-farm consumption supplemented with year-end changes of stocks) of Hungarian agriculture (HUF 2,313 billion) (Table 1). Their total assets (HUF 1,431 billion) accounted for nearly one third of the HUF 4,921 billion in total assets of farms engaged in commodity production and, at HUF 50.2 billion, one quarter of their pre-tax profits. Agricultural cooperations made one third of all agricultural investments by value (HUF 90 billion cf. HUF 259 billion) and provided 11.4 per cent of the 314,800 agricultural and food sector jobs. In terms of financial indicators (net revenue, total assets, profit before tax, investment) and the number of employees, the role of integrators among all forms of formal cooperation is outstanding, for example accounting for 80.5 per cent of net revenue.

The great importance of integrators is also demonstrated by the number of integrated farms. Enterprises contracting for production coordinate the production of almost 120 thousand farms (Table 1). By contrast, the agricultural cooperatives include 45 thousand producers, while the F&V POs have 15 thousand and the PGs have 14 thousand members. Machinery rings operating as formal organisations provide the opportunity for 1,300-1,500 farms to utilise their surplus capacity. Hungarian National Development Agency data show that about 40 clusters are engaged in agriculture and include 2,500-3,000 producers in their networks.

Table 1: Financial and other data for formal agricultural cooperations in Hungary by organisational form (2013).

Organisational form	Number of organisations	Net revenue	Total assets	Profit before tax	Investment	Number of employees	Number of members‡
		HUF billion				thousand	
Cooperative*	597	118.1	159.7	7.6	13.0	6.3	45
F&V PO**	79	54.7	50.1	0.04	5.6	0.6	15
PG**	201	273.6	68.1	1.0	1.4	1.0	14
Integrator***	615	1662.4	1190.1	43.9	72.7	29.3	120
Total****	1422	2064.9	1431.2	50.2	90.1	36.0	194

Note: * Agricultural cooperation registered by the National Tax and Customs Administration of Hungary (NTCA); ** subsidised organisations; *** organisations registered according to the regulation of the Hungarian Ministry of Agriculture and Rural Development No. 25/2004; **** without overlapping
Data sources: * NTCA; ** Department of Agricultural Markets of the Hungarian Ministry of Agriculture; *** County Offices of the Hungarian Ministry of Agriculture; ‡National Federation of Agricultural Co-operators and Producers Organisations

Table 2: Financial and other data for agricultural cooperations in Hungary by net revenue (2007 and 2013).

Net revenue category HUF billion	Number of organisations	Net revenue	Total assets	Profit before tax	Investment	Number of employees
		HUF billion				thousand
2007						
less than 0.5	1111	137.6	149.5	8.5	9.8	8.6
0.5-1.0	169	120.5	107.1	4.5	7.3	4.7
1.0-5.0	217	432.3	356.3	11.3	20.5	13.7
more than 5.0	64	1153.4	612.0	15.7	23.4	18.3
Total	1561	1843.7	1224.9	40.0	61.0	45.3
2013						
less than 0.5	908	113.7	164.6	6.2	10.4	5.8
0.5-1.0	202	147.3	137.6	5.4	12.7	4.2
1.0-5.0	241	514.2	481.5	20.2	36.9	11.0
more than 5.0	71	1289.7	647.5	18.4	30.1	15.0
Total	1422	2064.9	1431.2	50.2	90.1	36.0
Change: 2007=100%						
less than 0.5	81.7	82.6	110.1	73.4	106.1	67.4
0.5-1.0	119.5	122.2	128.5	120.0	174.0	89.4
1.0-5.0	111.1	118.9	135.1	178.8	180.0	80.3
more than 5.0	110.9	111.8	105.8	117.2	128.6	82.0
Total	91.1	112.0	116.8	125.6	147.7	79.5

Data source: NTCA

Table 3: Patterns of discussion of farm management issues among a sample of 1,000 farmers in Hungary (per cent).

Issue	Family member	Acquaintance	Business partner	Consultant	None of these
Production technology	54.5	22.0	26.9	7.0	22.8
Sale of farm produce	52.6	19.9	30.4	7.9	24.8
Cropping patterns	49.6	15.2	21.6	6.6	32.4
Plant protection measures	46.3	21.2	33.1	8.8	19.3
Agri-environment measures	28.7	11.2	23.3	10.3	42.0
Investment measures	24.7	8.9	18.0	11.2	55.6

Data source: survey conducted by the Institute for Sociology of the Centre for Social Sciences, and the Centre for Economic and Regional Studies, both of the Hungarian Academy of Sciences

By categorising agricultural cooperations according to annual net revenue, trends in concentration during the period 2007-2013 can be illustrated. While the number of organisations with a revenue of less than HUF 0.5 billion decreased by 20 per cent, there was a more than 10 per cent increase in the number of organisations with more than HUF 1 billion revenue (Table 2). In 2013 there were 71 organisations with more than HUF 5 billion annual net revenue and while they represent just 5 per cent of the total number of agricultural cooperations, they are dominating in the sector. They account for two thirds of the revenue of the cooperations (HUF 1,289.7 billion), 45.2 per cent of the total assets, 36.6 per cent of the profits before tax, 33.4 per cent of the investments and 41.7 per cent of the employment. Of these 71 organisations, 55 operate as integrators. They take 82.0 per cent of the net revenue generated in the given revenue category, have 86.2 per cent of the total assets make 86.7 per cent of the investment. Their shares of the profit before tax and employment are 97.3 and 98.0 per cent respectively.

The rate of development is shown by the fact that between 2007 and 2013 the number of these organisations increased by more than 10 per cent, their net revenue by 11.8 per cent, their total assets by 5.8 per cent, their investments by one quarter and their profit before tax by almost 20 per cent.

Cooperation from the farmers' perspective

Formal cooperation

Apart from their obligatory membership of the Hungarian Chamber of Agriculture, of the 1,000 farmers that completed the questionnaire 277 reported that they took part in some kind of formal cooperation. The most common forms of membership were of F&V POs, farmers' circles[6] and PGs (94, 85 and 60 farmers respectively). By contrast, just eight farmers were members of machinery rings and four of clusters.

The dominant role of the integrator companies in production is clearly illustrated by the fact that more than one third of the surveyed farmers stated that they purchase the inputs they require for plant production (for example seed, fertilisers and plant protection products) through integrator companies. Farmers who use this form of purchasing rely almost totally on the integrator companies and do not use any purchasing channels. As input suppliers provide loans for purchasing inputs, most farmers pay for inputs after harvest with produce or cash. A similar situation can be seen as regards sales of farm produce. Sales through integrator companies reach almost 100 per cent among the farmers who use this form of cooperation for their sales. Small quantities of grain are not easy to sell to companies dealing with large volumes. Sales though integrator companies are particularly significant among the farms producing grains, oilseeds and fruits and vegetables, but this channel is less significant for the sales of animal products.

Informal cooperation

For the following statements in the questionnaire, which farmers were asked to score on a 1-5 Likert scale (1 = strongly disagree; 5 = strongly agree), the mean results were as follows: "Most people are trustworthy": 3.4; "Most people are honest": 3.5; "People are just as honest as twenty years ago": 2.9; "You never can be too careful": 4.1. For each respondent, an aggregate value of the first three scores was used as a 'confidence index' in the following subsection of this paper.

Farmers were asked with whom they discuss farm-related matters. Around half of those completing the questionnaire discuss day-to-day farm management issues (production technology, sale of farm produce, cropping patterns and plant protection measures) with other family members (Table 3), while around one quarter discuss topics such as agri-environment and investment measures within the family. The share of farmers that discuss farm management issues with business partners is lower, ranging from 33.1 per cent for plant protection to 18.0 per cent for investment measures. The incidence of discussing issues with acquaintances is lower still, being in the region of 20 per cent for day-to-day issues and 10 per cent for agri-environment and investment measures. Fewer than 10 per cent of farmers discuss day-to-day issues with consultants but, by contrast, the opinions of consultants are slightly more frequently sought on the topics of agri-environment and investment measures. At least one in five farmers in the sample does not discuss a particular farm management issue with any of these groups of contacts. This figure exceeds two in five regarding agri-environment measures, and one in two for investment measures.

Correlations between cooperation factors

The parameters of the farms and the farmers used in this analysis were: size of agricultural area on the farm (ha), number of employees, age and gender of the farm manager, and the total number of Annual Work Units (AWU) spent on the farm. Attitudes to cooperation were measured by the use of services (for payment or in-kind; yes/no), confidence index (1-5 scale, derived as described above) and applica-

[6] Organisations supplying information and advocacy functions, operating as associations.

Table 4: Relationships between the parameters of the farms and the farmers in a sample of 1,000 questionnaire respondents in Hungary, farmers' attitudes to cooperation and different forms of cooperation.

Parameters and attitudes	Form of cooperation					Tender participation	Confidence index
	Membership	Discussion	Seed purchase	Service supply	Input purchase		
Agricultural area	0.125**	-0.108**	-0.010	-0.010	-0.004	0.063	-0.018
Number of employees	0.287**	0.115**	-0.031	0.002	-0.022	0.111**	-0.037
Age of farm manager	0.038	0.103**	0.002	0.027	0.071*	0.081*	0.048
Gender of farm manager	-0.080*	-0.140	-0.121**	-0.110**	0.143**	-0.031	0.005
AWU on the farm	0.169**	0.183**	0.209**	0.129**	0.143**	0.278**	0.031
Use of services	-0.027	-0.002	0.005	0.264**	-0.063*	-0.027	0.105**
Confidence index	0.027	0.035	0.116**	0.169**	0.084**	0.002	-
Tender participation	0.097**	0.183**	0.158**	0.114**	0.160**	-	0.002

Note: **/*: statistically significant, respectively at the 1% and 5% levels (2-tailed); for abbreviations see text
Data source: as Table 3

tion for investment funding from Pillar 2 of the CAP (yes/no). The forms of cooperation tested (yes/no) were whether the farmer is a member of any organisation (*Membership*), discussion of problems with others (*Discussion*), cooperation when purchasing grain seed (*Seed purchase*), supplier of services[7] (*Service supply*; for payment or in-kind) and cooperation when purchasing inputs (*Input purchase*). Zero values were included in the analysis.

Farmers with more agricultural land, more employees and/or whose farm employed more AWU were more likely to be a member of an organisation and more willing to discuss farm management issues with others (Table 4). Older farmers were also more willing to discuss issues. Relatively strong positive correlations were recorded between gender of the farm manager and the number of AWU spent on the farm and confidence index on the one hand, and cooperation in the purchase of inputs and grain seeds, and through the supply of services on the other. In other words, male farmers, those managing farms with a greater labour demand and those more inclined to judge others as being trustworthy and honest used these forms of cooperation more. Use of services by a farmer was correlated only with his/her supply of services (to other farms) whereas those farms that applied for investment funding from Pillar 2 of the CAP were more strongly involved in all forms of cooperation.

Managers of farms with more employees and those whose farms employed more AWU were more involved in applying for investment funding from Pillar 2 of the CAP, while those that used services recorded a higher confidence index. No significant correlations were recorded between the parameters of the farms and the farmers, and farmers' confidence index.

Potential for development of agricultural cooperation

The face-to face interviews covered the advantages and disadvantages of cooperation, the pitfalls and problems involved, and success factors.

Advantages and disadvantages of cooperation

The most frequently mentioned advantage of cooperation was economic benefits in the form of sales guarantees, higher selling prices for produce, cheaper inputs, lower transaction costs and greater access to credit. Regular exchange of information also appears as a benefit for members of cooperations. The interviewees highlighted that it is mainly the financially strong producers' organisations and integrator companies ensuring vertical cooperation that are able to provide these benefits. In addition, the interviewees mentioned the professional assistance benefits arising from cooperation. In particular, the producers' organisations and integrator companies of vertical integration provide extension as well as tax and legal advice. They also organise training for their members and provide beneficial services such as free water and soil quality tests, discounted rental of machinery and equipment, technology guidance, quality assurance, organising study tours and forums, writing applications, lending and pre-financing agricultural inputs. Integrator companies provide – in addition to their commercial activities – technology, consulting and financial engineering instruments, organise professional forums, highly customised specific training, presentations and events, distribute publications and provide machine parts supply and service. In the fields of social engagement, it is again clearly evident that the large and financially strong vertical integrators play an important role. Social benefits provided for the members include discounted meals, summer camps for children and the kindergartens. By contrast, most activities of the organisations of horizontal cooperation are only related to input sales and product purchasing.

The financially strong integrator companies operating as vertical cooperation adjust their lending strategies to their clients. In order to reduce risks and transaction costs, these large companies are often not in direct contractual relationships with the producers but rather with the locally operating 'intermediate integrators' which have the necessary local knowledge. Our interview results clearly showed the importance of this special operational form, which is characteristic for the Hungarian integrators. The 'intermediate integrators' are farms with large areas of land and assets, which integrate through contractual machinery services and by making available their storage and drying capacities to local producers that lack these assets. In general, this kind of cooperation covering a wide range of services is not casual but rather a long-term servicing relationship. In Hungary this kind of integration evolved in a self-organised manner at the end of the 1990s, generated by the need to gain access to machinery and assets. Via the integration based on the involvement of the intermediators, the integrator company can cut costs and

[7] For example plant protection, crop harvest, advisory services, returning nutrients to the soil.

risks arising from the unreliability of the clients. It is often the case in seed production that the intermediate integrators networking the small producers also benefit directly through the benefits obtained from volume purchases and in addition they sell their excess capacities (machinery, storage etc.) to the members of the network.

The interviewees reported that many producers consider that the compliance obligations and transparency are obstacles, despite the fact that these are the basis for cooperation. The disadvantage of cooperation could be that individual interests are subordinate to the community interests. Conflicts can arise because the cooperating actors are rivals as well.

Pitfalls and problems of cooperation

According to the interviewees, the main factor hindering cooperation is the 'black' economy and the 'black' market. The origin of the problem is the lack of resources, which tempts enterprises to put their own interests before the common interests. Therefore, in the hope of achieving higher revenue, they sell their products and services through the black market, and thereby they break their cooperation obligations. These companies are not interested in doing business in a transparent, traceable way.

As for the integrator companies, the survey results highlighted the inherent risk that the producers are not committed to one partner but rather associate with several integrators at the same time. The integrator companies for contract growing mitigate the inherent risks of the agreements by concluding contracts that include the possibility of holding the producers liable. The interviews with the managers of the producer organisations and integrator companies revealed that Hungarian farmers try to avoid long-term contractual relationships, mainly for reasons of risk aversion, low confidence and the sector's involvement in the black economy.

One of the problems mentioned by several interviewees is the effective dissemination of information. Above a certain number of members, close and intense contact with the members becomes difficult. A further pitfall of cooperation is that farmers are not motivated enough to train themselves and learn new professional skills and knowledge. The opinion of the interviewees is that the establishment of cooperation and its reliable operation are greatly complicated by the intricate and ever-changing regulatory environment in Hungary.

Success factors

The interviewees stated that it is important to enhance the interest of the members. Successful cooperators provide a wide range of high-quality services and personal client-centric contact with their partners. They typically operate in vertical form, covering the whole value chain and, in addition to the construction of distribution channels, their research and development activities and the dissemination of technological innovation are important features. The essential factor of the success minimises the risks. The interviewees mentioned good management primarily among success factors.

In the course of the interviews, in connection with the development of the producer organisations and integrator companies it became clear that the managers are interested in increasing the membership of the organisations as well as in improving the quality of the services provided. The survey showed that the producers' organisations can develop by improving the value-added of their products. The most important element of this is vertical integration along one commodity, which is the most efficient and provides most advantages and the establishment of secondary organisations and federations. Vertical cooperation will become even more concentrated, resulting in larger clusters and networks.

Discussion

In Hungary many forms of cooperation can be identified in the agricultural economy: by legal form, by the composition of the membership, by size, by the bargaining power and by the structures of activities. There are also signs of concentration in Hungary (as in other countries) in terms of trends related to cooperation. The economic importance of the nearly 1,500 domestic agro-cooperations is shown by the fact that their net sales almost equal the total annual output of agriculture (Table 1). Among the forms of formalised vertical cooperation, organisations coordinated by the integrator networks which offer business benefits, including security of purchases of inputs and sales of produce, are the most popular among farmers. The large integrator companies with more than HUF 5 billion in revenue play a very major role in the organisation of agricultural cooperation in Hungary. These large integrator companies prefer to cooperate with smaller 'intermediate integrators' which have local knowledge and direct links with farmers. In terms of financial indicators and employment the position of integrators is outstanding. Sales though integrator companies are particularly significant among the farms producing grains, oilseeds and fruits and vegetables, but less so for animal products.

By contrast, the level of formal horizontal cooperation between farmers in Hungary continues to be low, despite demonstrable advantages of horizontal cooperation (e.g. greater awareness, success is securing funding via tenders etc.). While the number of organisations involved in agricultural cooperation declined between 2007 and 2013, concentration of the organisations in terms of the economic weight and membership is observable (Table 1). While the low level of formal horizontal cooperation activity is no doubt partly due to the widely-reported problems of the risk avoiding behaviour of farmers and the low level of trust with potential partners and institutions, our interview results suggest that the role of the not tested non-cooperative, black market engagement with the enabling business and economic environment in hindering the emergence of formal relationships is also considerable. Therefore, our results add to the findings of earlier research on why the relationships between producers and horizontal integration in the last decade have in many respects remained essentially unchanged.

We provide quantitative data on the nature and extent of informal, horizontal cooperation among farmers in Hungary. Family members are dominant in discussing farm management issues (Table 3). The fact that many farmers do not consult anyone regarding agri-environmental or investment

measures is a concern. Generally, consultation is provided by the integrators as an additional service for their business partners and the role of consultants remains weak. This can indicate both lack of confidence or inefficiency in knowledge transfer, and represents a bottleneck in the development of cooperation in Hungary. The further development of an independent advisory system and consequent closer links between farmers and advisors based on trust will help to extend cooperation activity.

The analysis of the questionnaire data shows that the parameters of the farm do not influence the confidence index of the farm manager, but those with larger farms tend to participare more in membership organisations and in discussions with others. Several factors, including the gender of the farm manager, the number of AWU spent on the farm and the confidence index, are positively correlated with several forms of cooperation, including the purchase of inputs and grain seeds, and through supplying services to other farmers.

As regards future trends in agricultural cooperation in Hungary, the results of the interviews of leaders of professional organisations suggest that vertical integration will further concentrate and develop in the direction of building and shaping clusters and networks. Clusters and networks not only reduce transaction costs and stimulate the spread of new processes and technologies but also have a major role in organising new cooperative relationships. Our econometric analysis has shown that cooperation enhances the rate of success in tendering for funding and keeps partners better informed. Cooperating producers appeared to be more capable of economic development.

The main conclusion from our research is that the efficiency of agricultural economic cooperation is determined by both economic and social factors. The market players prefer verifiable cooperation based on confidence and which, in addition to reducing risk, allows them to increase their market share too. Therefore, in terms of market access the organised, concentrated vertical relationships are dominant in Hungary because in these organisations the accessible procurement advantages, tailored quality services and attainable innovations enhance the willingness of the producers to participate. The cooperations of high level vertical integration help producers to achieve a favourable negotiating position, and this narrows the development potential of horizontal cooperation in Hungary. However, the role of horizontal cooperation is significant in stabilising market relationships, reducing transaction costs, improving production standards and disseminating new technologies. Other widespread forms of cooperation are the mainly informal relationships providing assistance in accessing the basic agricultural services and utilising unused capacities; these are independent of the commodity and size and are characteristic for the Hungarian farms.

The Hungarian Rural Development Programme 2014-2020 provides a policy environment and integrated tools for stimulating cooperation. A development path for agricultural cooperation in Hungary could be for actors to formalise their existing informal relationships by organising themselves into alliances, associations and networks. This would allow farmers to increase value-added and utilise economies of scale, and give them a stronger bargaining position against integrators in vertical cooperation relationships. Beyond the benefits originating from market concentration, such formalisation could stimulate the sharing of expertise, improve the efficiency of advisory services and increase the innovation capacities of cooperation.

Acknowledgements

We thank the Institute for Sociology of the Centre for Social Sciences, and the Centre for Economic and Regional Studies for making data available to us from the questionnaire survey entitled ‘The market players of agriculture, development paths and policies of rural areas in Hungary’ which was carried out in the frame of a study funded by OTKA (NK 100675).

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FOGARASI József*‡[1], KEMÉNY Gábor*[2], MOLNÁR András*[3], KEMÉNYNÉ HORVÁTH Zsuzsanna*[4], ZUBOR-NEMES Anna* and KISS Andrea*

Modelling climate effects on Hungarian winter wheat and maize yields

Hungarian cereal production is situated in the zone of Europe which is most vulnerable to the effects of changes in climatic conditions. The objectives of this paper are to present the calibration and validation of the 4M crop simulation model using farm-level observed representative values, and to estimate the potential yields of winter wheat and maize production for the next three decades. Analysing the differences between the estimated and observed yields, we identified as key influencing factors the heterogeneity of technologies and of land quality. A trend of slightly decreasing yields is projected for the next three decades for both cereals. The precise impact of environmental change on crop yields will depend on which climate scenario occurs.

Keywords: crop simulation, climate change, yields

* Agrárgazdasági Kutató Intézet, Zsil utca 3-5, 1093 Budapest, Hungary. Corresponding author: fogarasi.jozsef@aki.gov.hu
‡ Also Partiumi Keresztény Egyetem, Oradea, Romania and Dunaújvárosi Egyetem, Dunaújváros, Hungary

Introduction

Agriculture is sensitive to changing temperature and precipitation patterns as well as to frequencies of extreme weather events. A growing number of studies have dealt with the impact of climate change on agricultural production and the farming sector (e.g. Mendelsohn *et al*., 1994; Chang, 2002; Seo and Mendelsohn, 2008; van der Werf, 2008; Wang *et al.*, 2009; Di Falco *et al*., 2011; Chang *et al*., 2012; Kaminski *et al*., 2013; Nelson *et al.*, 2014, Mitter *et al.*, 2015). The effects of climate change on agricultural production would highly depend upon the geographical location of the crop and animal production, with farms in some regions benefiting (Ghaffari *et al*., 2002) and farms in other regions suffering adverse effects under new climatic conditions (Jones and Thorton, 2003; Key and Sneeringer, 2014).

Modelling supply and market price adjustments of the European Union (EU) agricultural sector as well as technical adaptation to climate change, Shrestha *et al*. (2013) estimated an increase in yields and production volume. In general, there are relatively small effects at the EU aggregate level and stronger impacts at regional level with some stronger effects prevailing in the Central and Northern EU and higher impacts in Southern Europe. The most negative effects of climate change in Europe were found to occur in the continental climate in the Pannonian environmental zone, which includes Bulgaria, Hungary, Romania and Serbia (Olsen *et al*., 2011).

A growing number of recent studies provide evidence of climate change in Hungary (Spinoni *et al*., 2013) and on the likely effects of climate change on Hungarian agriculture (Fodor and Pásztor, 2010; Fodor *et al*., 2014; Gaál *et al*., 2014; Kemeny *et al*., 2014). These studies focus on biophysical and environmental consequences of climate change, and there are no empirical investigations on economic impacts of climate change on Hungarian agricultural production.

The objectives of this paper are, firstly, to estimate the impacts of climate change on yields in the Hungarian cereal sector using the 4M crop simulation model and, secondly, to assess the possibilities for technological adaptation with regression analysis. The 4M model has been applied in previous studies focusing on soil and weather influence (Máthé-Gáspár *et al.*, 2005), and on the effects of climate change on crop yields in Hungary (Fodor and Pásztor, 2010; Fodor *et al*., 2014). However, these studies are based mainly on experimental and non-representative farm-level data, whereas in this study we apply the model to representative Hungarian Farm Accountancy Data Network (FADN) data.

Methodology

Here we present the crop simulation and regression analysis models with the implementation settings and describe the data of the case study application.

Crop simulation model and implementation

The simulation of the effects of climate change on cereals yields is performed by using the 4M deterministic crop model. This mathematical programming crop model is adjusted to the Hungarian agro-technical and environmental conditions from the CERES model (Fodor *et al.*, 2002; Fodor, 2006). 4M is a daily-step deterministic model using input parameters of the atmosphere, soil and plant system. These input parameters are processed by the functions and equations of the model simulating the development and growth of plants and the heat, water and nutrient balance of the soil. The boundary conditions are primarily the daily meteorological data such as radiation, temperature and precipitation. The constraint conditions are the numerical expressions of human activities such as planting, harvesting, fertilisation and irrigation. In addition to plant development and growth, the model calculates the water, heat and nitrogen flows as well as the nitrogen transformation process of the soil.

The meteorological data include daily maximum and minimum temperatures and daily precipitation covering the area of Hungary with a one-sixth degree resolution grid, and were provided by the Hungarian Meteorological Service. The

[1] http://orcid.org/0000-0001-7989-8375
[2] http://orcid.org/0000-0002-1849-5991
[3] http://orcid.org/0000-0002-7010-7917
[4] http://orcid.org/0000-0003-2918-4977

Meteorological Interpolation based on Surface Homogenised Data Basis (MISH) interpolation technique (Szentimrey *et al*., 2005) was used for producing the grid of meteorological data from the local observations (Szépszó and Horányi, 2008; Szépszó *et al.*, 2011; Szépszó *et al.*, 2013). The soil use data are from the Hungarian Soil Information and Monitoring System (SIMS) covering clay, sand and organic matter soil types. The land use information was collected from the National Land Cover Database and was used to calculate agricultural areas within the meteorological cells used for simulation. The plant data, such as the phenological characteristics and stages, maximum root depth, light use efficiency and specific nitrogen content were determined from the relevant scientific literature (Fodor *et al.*, 2014). Agro-technical data such as planting date, plant density and fertiliser applications were provided according to the usual Hungarian agro-technology of each plant (Fodor *et al.*, 2014).

The calibration and validation of the crop simulation model

The calibration and validation of the 4M model was performed using actual crop fertilisation data as well as the observed yields for winter wheat and maize from the Hungarian FADN database for the period 2001-2012. The survey comprises detailed farm-level information on cost accounting, farming system and structural aspects.

The differences between the yields obtained from simulation and observed inputs were tested using equation (1):

$$Y_i = c + \beta_1 Y_{e,i} + \beta_2 dY_{e,i} + \beta_3 TC_i + \beta_4 LQ_i + e_i \quad (1)$$

where Y_i denotes the observed yield of every i farms, c is the constant term, $Y_{e,i}$ represents the simulated yields of the different farms by the 4M model, $dY_{e,i}$ is the difference of estimated yields of every farms from the average, TC_i and LQ_i denote deflated total costs and land quality of every farms obtained from Hungarian FADN survey data, e_i is the error term, and β are the parameters of the regression. The data used for the regression analysis are given in Table 1.

The effects of climate change on cereal yields

After validation of the model using observed Hungarian FADN data, the projections of the yields until 2050 were calculated based on the data of the farms selected for calibration and validation. The simulated yield values were adjusted using the parameters of the regression analysis.

The forecast of climate change is performed by the Hungarian Meteorological Service (*Országos Meteorológiai Szolgálat*, OMSZ) employing three regional climatic models from the ESSEMBLES project (van der Linden and Mitchell, 2009). The ALADIN, RACMO and REGCM models simulate different climate scenarios for the Carpathian Basin and Central and Eastern European regions respectively. These models are based on 50 km, 25 km and 10 km grids for the period 1951-2100, applying the newest emission scenarios. The model results are validated with observed data from the periods 1961-1990 and 1971-2000 and the projections are made for the periods 2021-2050 and 2050-2100 (Szépszó *et al*., 2013). The interpretation of climate simulation models results should be made taking into account the uncertainty due to the estimation of physical processes and human activities. The application of these three regional climatic models offers the opportunity of addressing these uncertainties, but for a more complete estimation the regional simulation results of the ENSEMBLES project with 25 km grid density were applied (van der Linden and Mitchell, 2009).

Table 1: Description of the data used for the regression analysis.

Parameter	Winter wheat	Maize
Number of farms	1,002	1,075
Number of observations	7,811	7,675
Average observed yield, t/ha^{-1} (Y_i)	4.16	6.48
Average estimated yield, t/ha^{-1} ($Y_{e,i}$)	4.21	6.50
Average total production costs, HUF/ha^{-1} (TC_i)	78,677	103,700
Average utilised agricultural area, ha	21.70	21.60

Source: own calculations based primarily on Hungarian FADN data

Results

The differences between observed yields and the yields estimated with the 4M model indicated the need for calibration and validation. After adaptation to the changed environmental conditions, the model was used for the projection of winter wheat and maize yields.

Calibration and validation

In comparison to the observed yields, the winter wheat and maize yields calculated by the 4M model were lower in the years with favourable climatic conditions for cereal production, and higher in the years with unfavourable climatic conditions. To improve the comparability of the simulated yields with the observed yields, only those farms with the smallest differences between observed and estimated yields were retained in the sample. Based on five-year farm-level data sets during the period 2001-2012, 1,002 winter wheat and 1,075 and maize producing farms were chosen. The 4M model was validated for these selected sample farms, the causes of differences between observed and estimated yields were investigated using regression analysis, and this validated crop simulation model was used to estimate the potential yields in the selected farms.

The regression analysis was based on estimated yield per hectare, difference of estimated yield per hectare, deflated total production costs per hectare and land quality parameters, and we found that main error source of the 4M model (the difference between observed and estimated yields) can be attributed primarily to heterogeneity of production technologies and the quality of land (Table 2).

In the calibration process, water stress and dry matter values were modified (Table 3). The calibration resulted in slightly higher coefficients of determination (R^2), but a more efficient indicator of calibration is the coefficient of variation of root mean square error – CV(RMSE). As a result of calibration we obtain values for CV(RMSE) that are closer to the critical value 40, when the estimated yields with the

Table 2: Regression analysis results of the selected sample of farms.

Parameter	Winter wheat	Maize
Estimated yield per hectare ($Y_{e,i}$)	0.284***	0.215***
Difference of estimated yields per hectare ($dY_{e,i}$)	0.045***	0.284***
Total production costs per hectare (TC_i)	0.305***	0.332***
Land quality (LQ_i)	0.183***	0.127***
Constant (c)	1.678***	1.534***
Adjusted R square	0.279	0.448

***/**/*: statistically significant, respectively at the 1%, 5%, and 10% levels
Source: own calculations based primarily on Hungarian FADN data

calibrated simulation model can be accepted. Validation of our calibrated 4M model indicated that we improved the estimation characteristics of the model, which can therefore be used for yield forecasts.

Climate effects on expected crop yields

The forecasted yields of winter wheat and maize as a consequence of changes in the climatic conditions without more efficient risk mitigation follow a slightly decreasing

Table 3: Calibration and validation results of 4M crop simulation model.

Calibration		Calibration values		Calibration/validation equation			Error indicators		
		Water stress	Dry matter	Slope	Constant	R square	Mean difference	RMSE	CV (RMSE)
Winter wheat	Initial	1.0	0.0022	0.5132	1.9952	0.1268	-0.0243	1.8322	44.1677
	Calibrated	1.6	0.0021	0.4660	2.3001	0.1465	0.0848	1.5953	38.4551
	Validated	1.6	0.0021	0.4767	2.1753	0.1486	-0.0173	1.5936	38.0350
Maize	Initial	1.0	0.0027	0.7456	0.6342	0.3112	-1.0030	2.9280	45.4956
	Calibrated	1.7	0.0029	0.7638	1.4661	0.3203	-0.0543	2.7494	42.7185
	Validated	1.7	0.0029	0.7401	1.4895	0.2969	-0.1776	2.8418	44.3074

Source: own calculations (4M model)

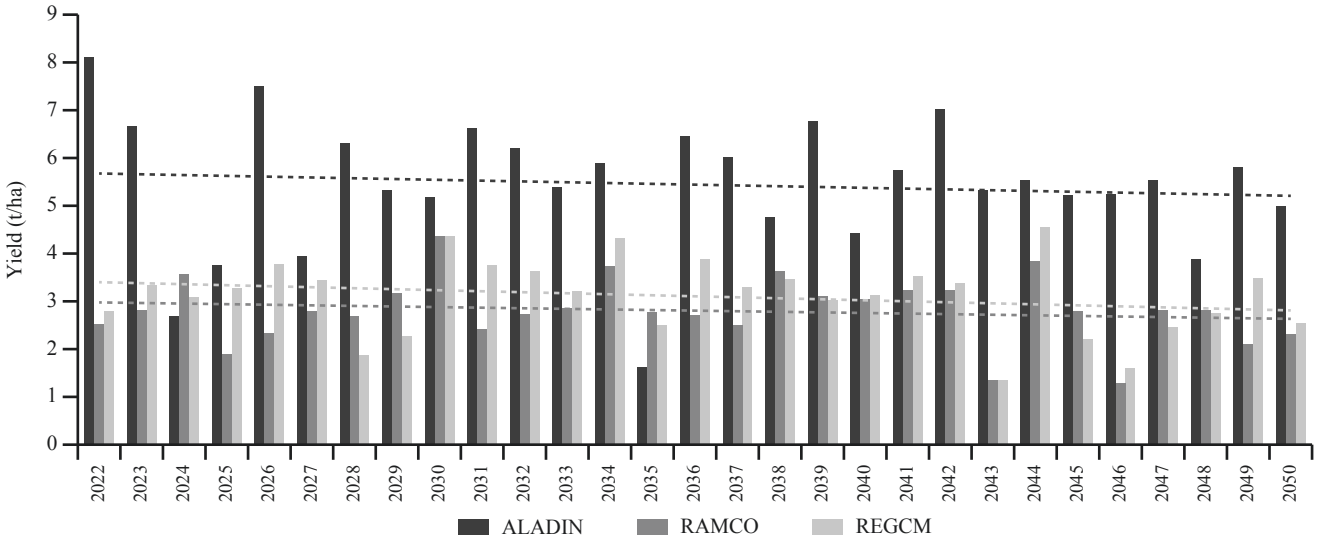

Figure 1: Winter wheat yield estimations according to three climate scenarios, 2022-2050.
Source: own calculations (4M model)

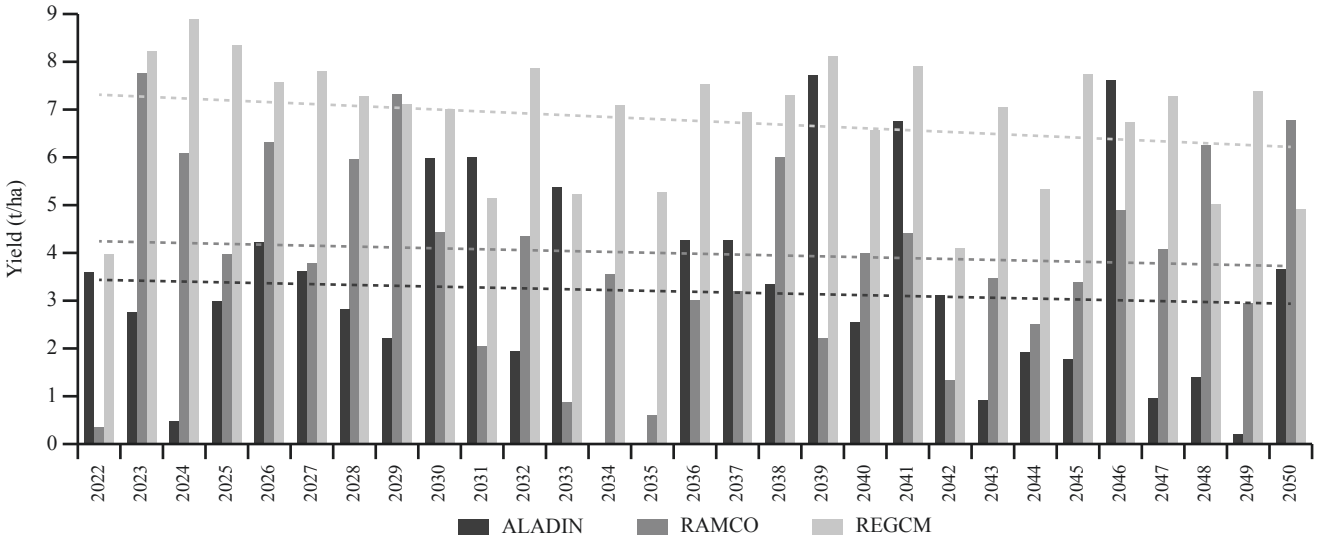

Figure 2: Maize yield estimations according to three climate scenarios, 2022-2050.
Source: own calculations (4M model)

trend in the coming decades (Figures 1 and 2). The average forecasted yields vary according to the climate scenario: for winter wheat and maize the estimated yields are close to current yields when the ALADIN and REGCM climate scenarios are considered, respectively. The predicted yields of winter wheat are sharply lower under the RACMO and REGCM climate scenarios while for maize production this trend is predicted under the ALADIN and RACMO climate scenarios. No climate scenario is favourable for both crops.

Considering farmers' resilience and adaptation to the changing climate conditions, we adjusted the yield projections obtained with the 4M model with the parameters of the regression analysis (Figures 3 and 4). After adjusting the technology, the favourable climate scenarios for winter wheat and maize result in lower yields and the unfavourable climate scenarios result in higher yields. In both cases the 'volatility' of yearly average yields is reduced as a result of farmers' risk mitigation arrangements.

Discussion

This paper investigates the impact of changes in climatic conditions on Hungarian winter wheat and maize yields using the linear programming 4M model and regression analysis to highlight the necessity of adaptation in private and public decisions (Antle and Capalbo, 2010). Previous studies (e.g. Fodor *et al.*, 2014) indicated that the 4M model provides realistic estimations for Hungarian crop yields. Other crop production optimisation models display similar performance at larger spatial scales (Moriondo *et al*., 2011; Liu *et al*., 2013).

Before calibration and validation, the simulated yields were systematically underestimated, but with the calibration and validation of the 4M model based on a Hungarian FADN representative sample of farms resulted in improved performance indicators (Table 2), the model is able to reproduce better the trend of observed yields variations. The regression parameters of the calibrated and validated 4M simulation

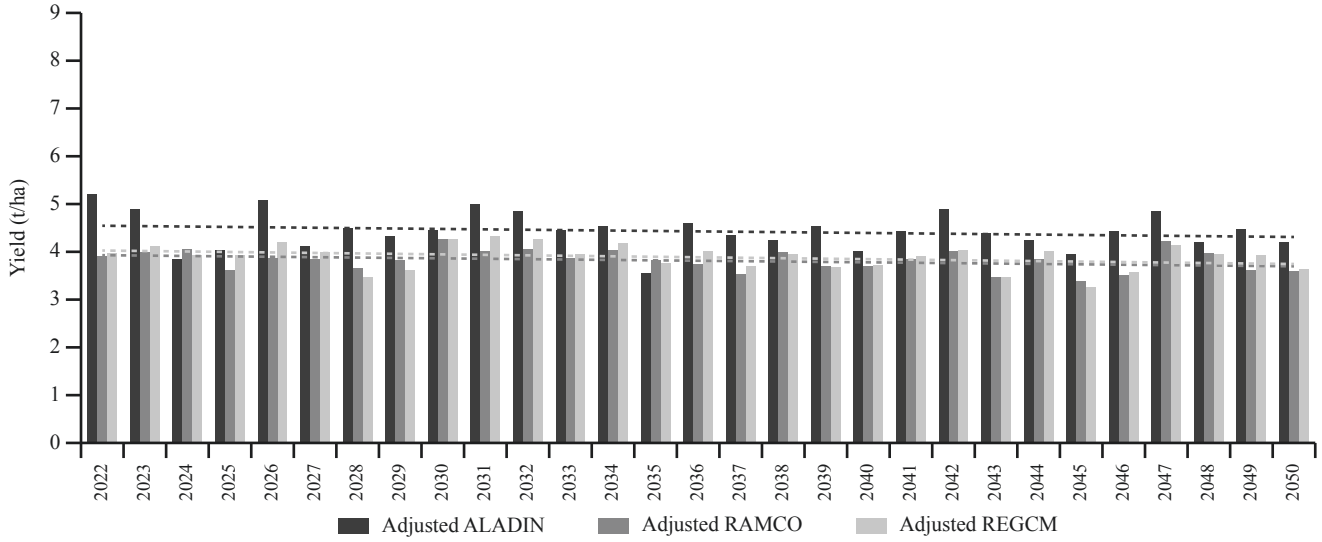

Figure 3: Adjusted winter wheat yields estimation according to three climate scenarios, 2022-2050.
Source: own calculations (4M model)

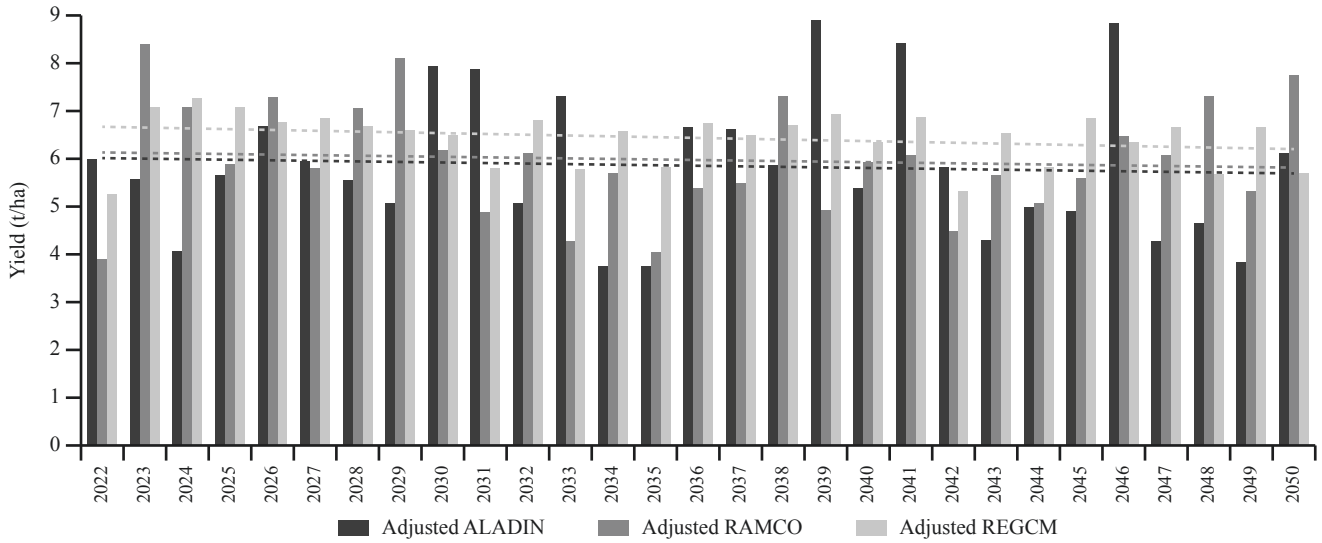

Figure 4: Adjusted maize yields estimations according to three climate scenarios, 2022-2050.
Source: own calculations (4M model)

results and the observed values indicate that the main factors causing the differences in the simulated and observed yields are the heterogeneity of production technology and land quality.

A slightly decreasing trend in the yields of both analysed crops is estimated for the next three decades due to the changes in climatic conditions. This trend for Hungarian crop production was also reported by Neményi (2015); his research shows that a sharp decrease in yields is expected in the second half of this century. This suggests that further investigations are needed to assess the capacity of Hungarian crop producers to adapt to the variations of climatic conditions that consider longer projections than those presented in this paper, changing sowing dates (Dobor *et al.*, 2016), and evaluation of different private and public adaptation measures.

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Amarendra Pratap SINGH* and Krishnan NARAYANAN*

How can weather affect crop area diversity? Panel data evidence from Andhra Pradesh, a rice growing state of India

This study analyses the temporal as well as the spatial shift in cropping pattern in Andhra Pradesh during the period from 1971 to 2009. The temporal associations between crop diversity, weather and economic variables have been examined to understand adaptation dynamics by means of cropping pattern shift. We find a significant impact of *rabi* (winter) season temperature and *kharif* (summer) season rainfall on cropping diversity. Along with mean weather, annual rainfall distribution has a significant, positive influence on crop diversity. The intra-seasonal distribution of dry days during *rabi* and *kharif* has a heterogeneous impact on crop diversity in districts of Andhra Pradesh. Within the state, geographical redistribution of rice area over the years can be considered as adaptation to climatic risk; however, sustainability of the emerging cropping pattern is under question due to a declining share of dry land crops during the study period. Drawing from the results, improving cropping intensity, increasing use of technology inputs and employing a season-wise incentive policy can be useful measures for sustainable diversification of the crop sector in the state.

Keywords: climate change, adaptation

* Indian Institute of Technology Bombay, Powai, Mumbai, 400076, India. Corresponding author: amarendra20383@gmail.com

Introduction

Adaptation of the agriculture sector to climate change is increasingly becoming a major developmental challenge. For meaningful adaptation intervention and mainstreaming adaptation with broader developmental goals, an enquiry into farmers' decision making is essential. With adaptation in mind, the number of studies analysing the decision making of farmers, both individual as well as collective, has grown manifold in past years (see, for instance, Bradshaw *et al*., 2004; Howden *et al*., 2007; Kurukulasuriya and Mendelsohn, 2008; Seo *et al*., 2008; Howe *et al*., 2014; Jain *et al*., 2015). *Agricultural diversification*, be it increasing the variety of production locations, crops, enterprises or income sources, is considered as a potential response to a variety of risks. In the case of climate change adaptation, *crop switching* has been considered as a major long-term response to minimise climate change impact on agriculture (Mendelsohn *et al*., 1994).[1] However, crop switching is a long-term phenomenon and can be best understood in terms of incremental shifts in the areas of a few crops which eventually transform the historical trends in *crop diversification/specialisation* (see Kates *et al*., 2012). In the context of developing countries, agricultural diversification is of critical importance not only for ensuring the economic well-being of the rural population but also for sustainability. From a policymaker's perspective, understanding climate impacts on agricultural diversification, in general, and on crop diversity, in particular, is essential to identify useful adaptation interventions (Figure 1).

Economic theory suggests that if farmers in a region detect climate trends correctly amid the noise of climate variability and they also have full knowledge regarding the climatic requirements of different crops, the cropping pattern must shift towards those crops which are more remunerative under changed climatic conditions (Zilberman *et al*., 2004; Burke and Lobell, 2010). In other words, if temperature is increasing then farmers will eventually shift farmed land towards heat tolerant and less water-intensive crops to cut the cost or revenue loss. However, climate-induced shift in cropping patterns may be a slow process due to lack of economic, institutional and policy incentives needed for adaptation (Adger *et al*., 2009; Zilberman *et al*., 2012). Additionally, the direction of weather-induced change in regional cropping pattern cannot be predicted, *a priori*. For example, a region which was diversifying earlier may begin specialising towards less water-intensive and heat-tolerant crops due to rising temperature. On the contrary, crop diversification may increase due to rising temperature in a region which was earlier specialising in production of water-intensive or heat-sensitive crops. Therefore, a test of temporal association between weather conditions and crop diversification is required to understand climate change adaptation by means of cropping pattern change. Having this objective in mind, this study analyses the relationship between crop diversity and weather in Andhra Pradesh, India.

India has been seeking to adapt its diverse agriculture sector to climate change. Within India, the coastal state of Andhra Pradesh is especially exposed to various climatic hazards such as drought, flood and wind (Kumar *et al*., 2006). While coastal districts of Andhra Pradesh are well endowed in terms of monsoon rainfall and irrigation, southern districts are rainfall scarce and face frequent drought incidents (WB, 2006). While farmers in Andhra Pradesh grow multiple crops due to its diverse agro-climatic characteristics, cropping pattern in the state is strongly biased toward rice. Rice contributes 77 per cent of total food grain production which amounts to 12 per cent of state Gross Domestic Product (MoA, 2003). Cotton, groundnut and maize are other important crops in the state. All the major crops in Andhra Pradesh can be harvested across the seasons: *kharif*, which is the main cultivation season during the summer, and *rabi*, which is the secondary winter cultivation season.[2] Since monsoon rainfall distribution across the state is very diverse, we have taken special care to model the impact of rainfall on crop diversity. Econometric results are juxtaposed against the

[1] While crop switching may be a possibility from a developed country's perspective; it seems unrealistic in a developing country's framework where subsistence farming coexists with a capitalist mode of farming.

[2] The crop calendar is available at http://eands.dacnet.nic.in/Advance_Estimate-2010.htm.

observed changes in the cropping pattern to explore future adaptation possibilities.

Background

Increasing supply of agricultural infrastructure and institutional support to ensure effective input supply, market expansion and diversification expands a farmer's choice set and eases constraints on adaptation to climate change (Kates *et al*., 2012; Banerjee *et al*., 2013; Jain *et al*., 2015). A society's adaptation efforts are closely linked with the economic growth and basic development indicators such as income, education and quality of institutions (Bowen *et al*., 2012). For example, Dell *et al*. (2009) have shown that increasing temperature has a more harmful impact on agriculturally dominated, least developed countries which possess poor physical and institutional infrastructure. Diversification of agriculture is an endogenous process and is closely associated with the structural transformation of an economy and economic growth (Pingali and Rosegrant, 1995). Earlier studies explored the nature and pattern of agricultural diversification across various regions and highlighted the role of various economic factors in explaining agriculture diversification. For example, Lichtenberg (1989) empirically tested a theoretical construct to show that technological innovations put significant impact on cropping pattern by affecting farmers' area allocation decisions. Ali (2004) provided an overview of agricultural diversification and international competitiveness of Asian countries and highlighted the need for improved infrastructure, technological progress and market reforms. Joshi *et al*. (2004), in an attempt to identify drivers of diversification towards the horticulture and livestock subsectors in South Asian countries, observed that urbanisation, roads and markets are major factors explaining diversification in these countries. Kurosaki (2003) highlighted the importance of markets in explaining crop specialisation in the Punjab region of south Asia. Singh *et al*. (2006) examined crop diversification of Indian provinces for two years (1991 and 2001) and concluded that risk mitigation was the driving force to explain diversification towards non-food crops in Indian states. The findings of this study also inferred that increasing supply of physical infrastructure (roads, irrigation and electricity) was a major factor explaining crop specialisation in Indian states. Rao *et al*. (2006) analysed agriculture diversification using district level data from India and concluded that urbanisation and dominance of smallholders were major determinants of agricultural diversification in post-liberalisation India.

Most of the earlier studies analysing agricultural diversification assumed climatic factors as fixed (for example, see Joshi *et al*., 2004) but this assumption is too restrictive. However, emerging adaptation literature provides enough evidence to show that farmers pursue various forms of diversification strategies depending on weather perception and resource availability. For instance, Kurukulasurya *et al*. (2008) and Seo *et al*. (2008) used farm level data from African countries to show that farmers account for weather conditions while making crop selection decisions. Fleischer *et al*. (2011) used survey data from Israeli farms to show that farmers adapt to different climatic conditions by choosing a bundle of crops and associated technologies. It was argued that the use of technological bundles instead of a single technology or crop allows more control of climate and other physical impacts. In a study based on a survey of farmers in semi-arid tropical regions of India, Jain *et al*. (2015) observed that investments such as installation of tube wells which were made to reduce weather risks have worked to increase land devoted to risky but remunerative crops. Vijaysarathi and Ashok (2015) surveyed farmers in Tamil Nadu, India to examine the determinants of climate adaptation and to measure the impact of climate adaptation measures on technical efficiency of agriculture and found that climatic factors significantly explain probability of cropping pattern change. This study also points out that awareness regarding climate change increases probability of cropping pattern change. In a study to show the process of farmers' adaptation in the context of multiple exposure in Akita Prefecture, an apple producing region of Japan that has shifted to peach farming, Fujisawa and Kobayashi (2013) observed that spontaneous change in cropping pattern took place due to interregional communication among farmers.

Methodology

Data

The data used in this study come from two sources. Information on yearly crop area, net cultivated area, gross cultivated area, area under high yielding variety (HYV) seeds, and irrigation come from the Village Dynamics in South Asia (VDSA) database of the International Crop Research Institute for Semi-Arid Tropics (ICRISAT), Patancheru, India. ICRISAT also provides data on agriculture labourers and cultivators[3]; however, information on these factors is available only at decadal intervals. Gaps in census data are filled by using a linear interpolation method. Daily gridded rainfall and temperature, interpolated at the district level, are extracted from the National Innovations on Climate Resilient Agriculture website (http://www.nicra-icar.in). While agricultural data are available for longer periods, we consider the longest time span from 1971 to 2007 for econometric analysis for which climate data are available. Additionally, district boundaries in the ICRISAT database are defined according to the 1967 status and data of newly-formed districts were given back to the parent district, leaving only 20 districts in the ICRISAT dataset. Of the 20 districts in Andhra Pradesh which existed before 1967, three new districts, Vijiyanagaram, Rangareddy and Prakasam, have been carved out to increase the number of districts in the state 23. To remove this discrepancy in the two datasets, we use the parent district's climate distribution as a proxy of the undivided district's climate.

[3] For purposes of the census in India a person is classified as 'cultivator' if he or she is engaged in cultivation of land owned or held from the Government or held from private persons or institutions for payment in money, kind or share. Cultivation includes effective supervision or direction in cultivation. A person who has given out her/his land to another person or persons or institution(s) for cultivation for money, kind or share of crop and who does not even supervise or direct cultivation of land is not treated as cultivator. Similarly, a person working on another person's land for wages in cash or kind or a combination of both (agricultural labourer) is not treated as cultivator.

Variables

Dependent variable

The dependent variable is the Simpson's diversification index which reduces crop related area share to a scalar number. A zero to one scale diversification index represents the probability of having different crops when two parcels of land are chosen randomly (Pope and Prescott, 1980). The more specialised is the cropping pattern, the closer is the diversification index to zero. A discussion on variable construction is provided below.

Explanatory variables

Climate variables: Both temperature- and rainfall-related variables for each season are constructed using daily weather data. Average *rabi* temperature is measured by averaging daily temperature from the months from November to February. Similarly, we have averaged daily temperature data from July to September to represent average *kharif* temperature. A similar methodology has been applied for getting a measure of average rainfall in two seasons. As per the crop calendar of the state provided by the Indian Ministry of Agriculture and Farmers Welfare, the weather during these months is the best representative of the climate relevant for agricultural activities in these seasons.

Many districts in the state fall in a scarce rainfall zone; therefore, monsoon rainfall is a major constraint on the choice of crop mix. Mean rainfall in rainfall-scarce districts is less than the state average (WB, 2006), therefore it is important to analyse the impact of rainfall on crop diversification more carefully. At a district scale, land allocation decisions, in any season, are spread over several weeks to avoid risk related with moisture availability. In rain shadow regions[4] of the state, farmers have had to re-sow the seed because of the delay in the onset of the rainfall followed by dry spells (Banerjee *et al*., 2013). While access to irrigation reduces crop failure risk, it negatively affects agricultural profitability. Additionally, risk related with rapid loss in soil moisture is high during the *rabi* season due to sporadic and infrequent rainfall. We take the number of dry (no rain) days as a proxy for moisture availability (Pandey and Ramshastri, 2001) and examine the impact of intra-seasonal frequency of rainfall days on crop diversity. Using data from ICRISAT villages located in Andhra Pradesh and Maharashtra, Jodha (1977) observed that annual rainfall distribution is an important determinant of cropping pattern in these villages. We take rainfall intensity, defined as the ratio of maximum rainfall in any month of a year and total annual rainfall, as a proxy for inter-month rainfall distribution. This variable takes a value 1 if the entire rainfall in a year falls in one month. In the case of evenly distributed rainfall, it takes a value 1/12.

Economic variables: Apart from climate-related factors, we have also considered non-climatic factors in the econometric model and the justification for inclusion of these variables is as follows. Access to modern irrigation facilities is an important prerequisite for using yield enhancing agricultural inputs such as fertilisers and pesticides. A lack of modern irrigation facilities is a major impediment to agricultural growth (Kurosaki, 2003). Irrigation is also important from the adaptation perspective as it helps to minimise climate change pressure on the existing cropping pattern. However, irrigation may not be conducive for crop diversification as it reduces risk by homogenising moisture conditions irrespective of the climatic conditions (Benin *et al*., 2004).

Cropping intensity is a measure of resource use efficiency in agriculture. Cropping intensity measures the frequency of agricultural land use in a calendar year. Most of the major crops in the state including rice are cultivated across the seasons. In that case, cropping intensity and specialisation will move in same direction; however, crop diversification may increase with rising cropping intensity when the inter-seasonal difference in climatic conditions is large. Most of the non-*kharif* months in the state receive nominal rainfall; therefore, cultivation of water-intensive crops may turn out to be cost-intensive. Another important factor which explains crop diversity is the share of area under HYV seeds. Increasing the area under HYV crops may promote crop diversification by fulfilling food requirements by using relatively less cultivable land. Another effect of HYV crops on crop diversification can be considered in terms of increased agricultural surplus which enables farmers to invest in intensive cropping. Availability of labour affects agriculture decisions too, as abundant labour supply allows cultivation of labour-intensive crops such as fruits and vegetables (F&V) which are crucial for profitable diversification (Rao *et al.*, 2006). In this study, both cultivators and agricultural labourers are considered as 'labour', considering the extensive use of family labour in farms in India.

Based on the discussion above, we hypothesise the following econometric model which is quadratic in climate variables:

$$\begin{aligned} Diversification_{it} = {} & \alpha_i + g(t) + \beta_1(Temperaturekharif)_{it} + \\ & \beta_2(Temperaturekharif)^2_{it} + \beta_3(Temperaturerabi)_{it} + \\ & \beta_4(Temperaturerabi)^2_{it} + \beta_5(Rainkharif)_{it} + \beta_6(Rainkharifi)^2_{it} + \\ & \beta_7(Rainrabi)_{it} + \beta_8(Rainrabi)^2_{it} + \beta_9(Rainintensity)_{it} + \\ & \beta_{10}(Drydayskharif)_{it} + \beta_{11}(Drydaysrabi)_{it} + \\ & \beta_{12}(Labourperhectare)_{it} + \beta_{13}(Irrigationshare)_{it} + \\ & \beta_{14}(Croppingintensity)_{it} + \beta_{15}(HYVshare)_{it} + \varepsilon_{it} \end{aligned} \quad (1)$$

where α_i stands for district specific intercepts, $g(t)$ represents quadratic time trend which captures impact of change in policy regime on crop diversity and β's are common slope coefficients. ε_{it} is the random error term associated with the district i at time t.

Methods

Trend analysis

For examining various trends in the area distribution we use simple ratios and compound annual growth rate (CAGR). We have taken a five-year moving average of data to analyse

[4] A rain shadow region is an area having relatively little precipitation due to the effect of a topographic barrier, especially a mountain range, that causes the prevailing winds to lose their moisture on the windward side, causing the leeward side to be dry.

trends and pattern in area distribution. We estimate CAGR using a time series model in the form of: $\ln A_t^i = a + b_t + u_t$ where, A_t^i is area under crop i, t is measured in years and u_i is an *iid* error term. CAGR is produced as: $antilog(b)-1$ (Gujrati and Sangeetha, 2007).

Panel unit root test

Deterministic and stochastic trends in variables can introduce spurious correlation between the variables because the error associated with the data generating process of both variables might be integrated (Granger and Newbold, 1976). Earlier, it was believed that inclusion of a deterministic time trend in regression can solve the problem of trending variables, however, now it is well known that correlation between the variables can still be spurious when the time trend is included. Therefore, it is necessary to test stationarity to examine presence of a deterministic and stochastic trend in macroeconomic time series. A stationary time series is integrated at order 0 or $I(0)$ and those time series which are integrated at higher orders can be made stationary by differencing the time series. To test stationarity in the panel variable y_{it}, which stacks data for N units over T time periods, a first order autoregressive data generating process of following type is assumed:

$$y_{it}=(1-\phi_i)\mu_i+\phi_i y_{i(t-1)}+\varepsilon_{it} \quad i=1,2,\ldots,N;\ t=1,2,\ldots,T \tag{2}$$

where initial values y_{i0} is given and we test null hypothesis of unit roots $\phi_i = 1$ for all i. The data generating process can alternatively be represented as:

$$\Delta y_{it}=\alpha_i+\beta y_{i(t-1)}+\varepsilon_{it} \tag{3}$$

where $\alpha_i=(1-\phi_i)\mu_i$ and $\beta_i=-(1-\phi_i)$ and $\Delta y_{it}=y_{it}-y_{i(t-1)}$. In this case, the null hypothesis to be tested becomes:

$H_0: \beta_i = 0;$ for all i,

against the alternative:

$H_0: \beta_i < 0;$ for $i=1,2,\ldots,N_1,\ \beta=0;$ for $i=N_1+1,\ldots,N.$

Based on this construction, Im *et al*. (2003) suggested three different tests statistic under different assumption regarding N and T.

Pesaran's LM test for cross sectional dependence

Consider the standard panel data model with time series dimension T ($t = 1, 2, 3, \ldots, T$), cross sectional dimension N ($n = 1, 2, 3, \ldots, N$) and number of parameters to be estimated is k. Typical error term ε_{it} is assumed to be independently and identically distributed over time periods and cross sectional units. Under the alternative hypothesis, ε_{it} may be correlated across cross sections, but the assumption of no serial correlation remains. Pesaran (2004) proposes a Lagrange multiplier (LM) test for cross sectional dependence which is defined by:

$$CD = \sqrt{\frac{2T}{N(N-1)}\left(\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}\hat{\rho}_{ij}\right)} \tag{4}$$

in which:

$$\hat{\rho}_{ij}=\hat{\rho}_{ji}=\frac{\sum_{t=1}^{T}\hat{\varepsilon}_{it}\hat{\varepsilon}_{jt}}{\left(\sum_{t=1}^{T}\varepsilon_{it}^2\right)^{1/2}\left(\sum_{t=1}^{T}\varepsilon_{jt}^2\right)^{1/2}}$$

Under the null hypothesis of no cross sectional dependence, Pesaran (2004) demonstrated that CD is normally distributed for $N\to\infty$ and T sufficiently large.

Results and discussion

Cropping pattern in Andhra Pradesh

Whether crop diversification in the past implies adaptation to climate change or not can be understood retrospectively. Past movements in the cropping pattern can be indicative for future adaptation planning. Past patterns in crop diversity can also be useful to explain econometric findings. For these reasons, we provide a brief review of past changes in area distribution in the state at different levels of aggregation.

In terms of area, a major shift in cropping pattern from food grains to non-food grains can be observed in Andhra Pradesh during the study period (Table 1). While the share of coarse cereals has been diminishing continuously, maize has benefitted from liberalisation-induced market expansion. Maize occupied around 2 to 3 per cent of the total area until 1990 but accounted for more than 6 per cent in 2009. The area share of oilseeds increased from 17.8 per cent in 1970 to 24.6 per cent in 1990, but then declined in the post-liberalisation period. Similarly, pulses held a 12 per cent share of

Table 1: Growth and distribution of crop area in Andhra Pradesh, 1970-2009.

	Share in total gross cropped area (%)					Area growth rate (per cent per year)			
	1970	1980	1990	2000	2009	1970-1979	1980-1989	1990-1999	2000-2009
Rice	29.4	33.4	34.1	34.0	32.0	0.84 (4.07)	-0.19 (-0.91)	-0.14 (0.00)	0.16 (0.26)
Sorghum	23.5	20.3	10.9	5.9	2.7	-0.79 (-4.50)	-2.20 (-27.31)	-2.50 (-35.04)	-3.96 (-12.71)
Maize	2.2	2.8	2.5	3.7	6.6	1.01 (8.13)	-0.29 (-2.30)	1.45 (6.80)	3.12 (12.34)
Groundnut	12.5	11.7	19.3	15.3	13.2	-1.28 (-4.30)	2.07 (8.95)	-1.10 (-6.07)	-0.45 (-1.86)
Sugarcane	1.3	1.2	1.4	2.7	2.9	0.81 (2.15)	0.26 (0.67)	1.50 (4.42)	0.92 (0.91)
Cotton	2.8	3.6	5.4	9.1	10.8	0.83 (2.00)	2.09 (10.01)	2.75 (20.32)	0.83 (1.74)
Fruits & vegetables	2.5	2.9	4.4	7.0	8.5	0.90 (3.64)	1.94 (13.27)	2.20 (54.66)	0.92 (15.90)

Figures in parentheses are *t* values
Data source: VDSA database, ICRISAT

Table 2: Area distribution of major crops within regions of Andhra Pradesh, 1970-2009*.

Region	Year	Rice	Sorghum	Maize	Groundnut	Sugarcane	Cotton	Fruits & vegetables
	1970	56.9	3.1	0.3	7.1	3.8	0.1	5.6
	1980	61.3	2.0	0.5	5.4	3.2	0.1	6.8
Coastal Northern	1990	58.3	0.7	0.5	8.0	3.5	0.4	8.9
	2000	54.4	0.2	1.2	5.7	6.3	0.9	13.1
	2009	52.6	0.1	3.4	3.4	8.2	0.9	15.4
	1970	47.4	18.8	0.2	5.4	0.7	0.9	2.8
	1980	49.8	13.0	0.2	4.0	0.8	4.9	3.2
Coastal South	1990	47.9	3.9	0.5	6.7	0.9	10.0	4.6
	2000	49.2	0.4	1.1	2.1	1.7	11.1	7.3
	2009	48.5	0. 5	4.8	1.5	1.8	10.7	8.3
	1970	15.8	34.4	4.3	6.7	1.2	3.7	0.7
	1980	19.8	33.9	5.9	6.1	1.1	5.1	0.8
Inland North Western	1990	21.2	28.8	6.1	8.1	1.4	8.1	1.5
	2000	21.8	19.2	8.4	5.9	2.9	10.6	2.9
	2009	18.6	7.1	13.2	4.6	2.7	16.4	4.3
	1970	14.3	23.5	0.1	31.4	1.0	7.6	2.5
	1980	16.3	20.6	0.1	34.3	0.9	6.8	3.1
Inland Southern	1990	12.1	9.4	0.1	56.2	1.0	3.3	4.1
	2000	11.6	4.9	0.2	48.6	2.0	6.0	6.5
	2009	10.2	3.7	1.2	43.9	1.8	1.6	7.6
	1970	21.6	32.0	5.5	8.0	0.0	0.2	0.6
	1980	28.5	26.9	6.5	6.0	0.1	0.1	0.6
Inland North Eastern	1990	37.3	9.3	5.3	11.3	0.2	5.5	2.3
	2000	41.1	2. 8	8.1	6.2	0.3	18.3	4.1
	2009	39.9	1.0	10.7	3.7	0.4	26.5	6.1

* Classification of districts into agro-ecological regions is based on the information provided by the National Sample Survey Office (http://mospi.nic.in/Mospi_New/upload/nsso/nss_regions.pdf); inland south and inland north-west region include districts falling in the rainfall and irrigation scarce zone of the state
Data source: VDSA database, ICRISAT

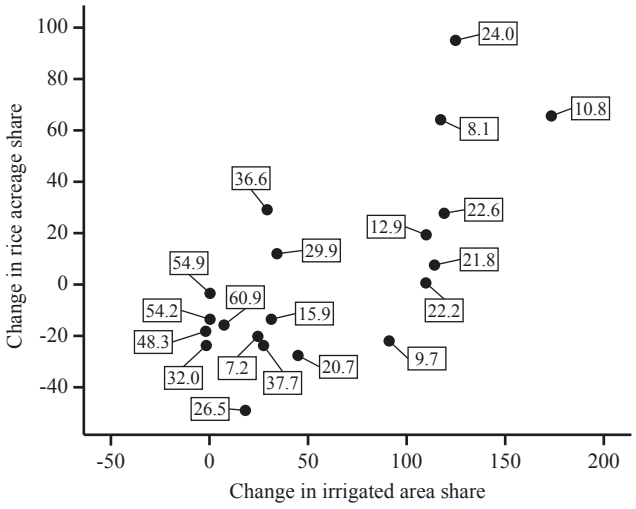

Figure 1: Change in rice area share due to irrigation expansion in districts of Andhra Pradesh. (Boxes show the area share of rice in 1970).

Data source: VDSA database, ICRISAT

the total area until 2000, but declined thereafter. Among non-food grains, the area share of F&V crops has been increasing since 1970, although the rate of growth has decelerated after 2000. Groundnut share in total area, after peaking in 1980, has declined considerably in the post-liberalisation period.

At the regional level, a clear redistribution of the rice growing area can be identified. Losses in area share in coastal north and inland south have been overcompensated by gains in inland north regions. (Table 2). But while rice is expanding in new areas, the share of groundnut in total area has declined in all regions except in the inland south region which falls in the rainfall scarce semi-arid region of Andhra Pradesh.

Figure 1 depicts the change in the irrigated area share against the change in the rice share for all districts, while the share of rice in the total area in the initial period (1970) is reported in rectangular boxes. Districts which used to dominate rice cultivation have shifted area towards other crops. On the other hand, districts which witnessed higher gains in terms of irrigation have added new area to rice cultivation, barring a few exceptions. While increasing area under rice adds to the vulnerability of the agricultural system by compounding pressure on groundwater resources, it cannot be denied that spatial distribution of the rice area in the state has helped agriculture to adapt by distributing risk related with rice production (Smit *et al*., 2000).

To examine the impact of area redistribution on crop diversity, Figure 2 plots the diversification index for median, top 25 per cent and bottom 25 per cent in each year for all districts along with the state.[5] The diversification plot for the top 25 per cent of districts shows an increasing trend over the study period while the plot for the bottom 25 per cent indicates a sustained shift toward diversification after a wave of specialisation observed before 1991. Finally, a higher province-level plot than the median of districts plot suggests that cropping pattern is more specialised at the district level

[5] Median index value of the top five most diversified districts out of 20 districts is termed as the top 25 per cent. Similarly median index value of the five least diversified districts is termed as the bottom 25 per cent.

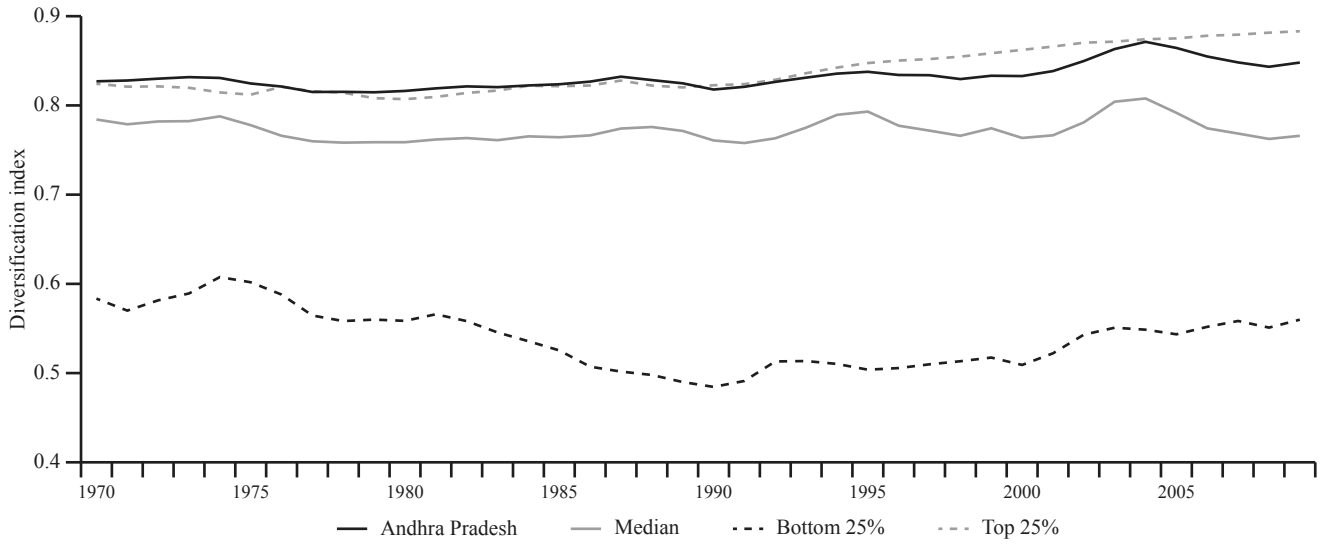

Figure 2: Trends in crop diversity at district and state level in Andhra Pradesh, 1970-2009.
Data source: VDSA database, ICRISAT

Table 3: Definition of variables used in the econometric model (equation 1) and summary of data (n=740).

Variable	Definition	Unit	Mean	Std. dev.	Min	Max
Diversification Index	$1-\sum_{i}^{n}\left(\frac{A_i}{\sum A_i}\right)^2$; Where A_i is the area under crop i, n is the number of crops	-	0.7	0.1	0.3	0.9
Temperature *kharif*	Average of June to September daily temperature	ºC	29.8	0.9	27.1	32.0
Temperature *rabi*	Average of November to February daily temperature	ºC	24.1	0.7	21.8	26.2
Rainfall *kharif*	Average of June to September daily rainfall	mm	132.9	55.8	29.0	386.1
Rainfall *rabi*	Average of November to February daily rainfall	mm	22.0	25.9	0.0	191.0
Rainfall intensity	Maximum rainfall in a month/total annual rainfall	-	0.3	0.1	0.2	0.5
Dry days *kharif*	Days without rainfall from July to September	Number	15.6	7.4	0.0	39.0
Dry days *rabi*	Days without rainfall from November to February	Number	102.3	13.0	31.0	120.0
Labour per hectare	Number of agricultural labourers and cultivators/total population	-	1.5	0.4	0.6	3.1
Cropping intensity	Gross cultivated area/net cultivated area	-	121.0	17.2	100.5	183.3
Irrigation share	Net irrigated area/net cultivated area	-	40.1	19.3	3.5	88.7
HYV share	Total area under HYV seeds/gross cropped area	-	36.4	23.6	1.0	56.0

Source: own calculations

than at the state level.

Demand-led growth in the share of F&V crops in India has been supported by an increasing network of public infrastructure as well as a favourable policy environment for investment in food processing (Birthal *et al*., 2008). However, lethargic growth in the area of F&V crops indicates a need for more dedicated incentives and infrastructure. Increased imports of cheap oil under WTO obligations has been a major factor explaining the declining area share of oilseed crops (Reddy and Bantilan, 2012). The decline in the shares of pulses and oilseeds in the state reflects poor implementation of *Pulses and Oilseeds Mission* in the state and is a matter of concern from an adaptation perspective. Sustainability of the emerging cropping pattern which is biased against dry-land crops is critically dependent on irrigation infrastructure. Technological intervention along with subsidised supply of farm inputs and high incentive prices seems important to explain the specialisation wave in the state during the 1970s and 1980s; however, diversification brings crucial adaptation benefits. Rainfall distribution seems vital to explain highly diversified cropping pattern in a few districts, especially in southern Andhra Pradesh.

Determinants of crop diversity

Here we examine the impact of weather on crop diversity over time in districts of Andhra Pradesh. Considering a large time dimension (T=37 years; N=20) of the panel, it is imperative to examine time series properties of the data. In this regard, we have used the unit root test developed by Im *et al*. (2003) and find that all variables are stationary at level.

Table 3 lists the definitions of the variables of the regression model given in equation 1 and Table 4 reports the parameter estimates. We start with estimating the fixed and random effects model. The Hausman (1978) test statistic for fixed versus random effects specification is 45.1 (p-value=0.000) which infers that parameter estimates of the model specified with fixed effects (FE) are preferred over random effects (RE). However, the assumption of homoscedastic errors in the estimated FE model is refuted due to high significance of modified Wald test statistic (Baum, 2001). Similarly, cross-sectional correlation can be a potential problem in panels dealing with data on geographical entities. We also examine the presence of cross-sectional dependence in errors using a test proposed by Pesaran (2004). A high level of statistical significance of the

Table 4: Climatic and economic determinants of crop diversification in 20 districts of Andrha Pradesh (n = 740).

Independent variables	Dependent variable: Simpson's diversification index		
	Fixed effects model	Random effects model	Fixed effects model with corrected SEs
Climatic factors			
Temperature *kharif*	-9.11 (0.147)	-6.02 (0.149)	-9.11 (0.281)
Temperature *kharif* sq.	0.152 (0.0025)	0.100 (0.0025)	0.152 (0.0047)
Temperature *rabi*	-0.278* (0.154)	-27.10* (0.157)	-0.278** (0.123)
Temperature *rabi* sq.	0.0057* (0.0032)	0.55* (0.0033)	0.0057** (0.0026)
Rain *rabi*	0.032 (0.0223)	2.82 (0.0227)	0.032 (0.0227)
Rain *rabi* sq.	-0.028* (0.0158)	-2.56 (0.0161)	-0.028 (0.0175)
Rain *kharif*	-0.031* (0.0174)	-2.98* (0.0177)	-0.031* (0.0154)
Rain *kharif* sq.	0.0082* (0.0049)	0.797 (0.0050)	0.0082* (0.0045)
Rain intensity	5.70 (0.0357)	6.42* (0.0364)	5.70* (0.0322)
Dry days *kharif*	-0.055 (0.0004)	-0.0532 (0.0004)	-0.055** (0.0002)
Dry days *rabi*	0.028 (0.0002)	0.0287 (0.0002)	0.028* (0.0002)
Economic factors			
Irrigation share	-0.107*** (0.0003)	-0.153*** (0.0003)	-0.107** (0.0005)
Labour per hectare	4.94*** (0.0108)	4.69*** (0.0108)	4.94*** (0.0124)
Cropping intensity	0.116*** (0.0003)	0.0879*** (0.0003)	0.116*** (0.0003)
HYV share	0.033** (0.0148)	0.0311** (0.0151)	0.033*** (0.0115)
Trend	-0.561*** (0.0009)	-0.511*** (0.0009)	-0.561*** (0.0008)
Trend sq.	0.0127*** (1.99e-05)	0.0123*** (2.03e-05)	0.0127*** (1.63e-05)
Constant	531.40** (2.640)	482.30* (2.680)	5.314 (3.809)
R-squared (within)	0.134	0.129	0.134
Model goodness of fit	F (17, 703) = 6.40***	Chi-squared (17) = 106.81***	F (17, 36) = 78.28***
Hausman test (fixed vs random effects) [a)]	Chi-squared (17 df) = 45.05***	-	-
Modified Wald test for group-wise heteroscedasticity in fixed effect regression model [b)]	Chi-squared (20 df) = 3735.66***	-	-
Pesaran's LM test of cross sectional independence	Chi-squared = 2.89***; Average absolute value of the off-diagonal elements = 0.34	-	-
Wooldridge test for autocorrelation in panel data [c)]	F (1, 19) = 78.40***	-	-

***/**/*: statistically significant at the 1%, 5%, and 10% levels respectively; all coefficients are multiplied by 100; figures reported in parentheses are standard errors; rainfall data which are given at millimetre scale in the original dataset are rescaled to decimetres to make coefficients more reasonable; standard errors reported in the last column are corrected for cross sectional dependence using the Driscoll-Kraay (1998) method

[a)] H_0: difference in coefficients is not systematic i.e. random effects coefficients are efficient and consistent under H_0

[b)] H_0: $sigma_i^2 = sigma^2$ for all *i*, i.e. error variance is constant across all districts

[c)] H_0: no first order autocorrelation

Source: own calculations

Pesaran's test statistic causes us to reject the null hypothesis of no cross sectional dependence. Additionally, the Wooldridge (2002) test is used to examine the presence of serial correlation in errors and a significant test statistic confirms that errors are serially correlated in the FE model.

Considering that errors in the FE model do not satisfy the least squares assumptions, standard errors of FE model estimates are not reliable. However, FE model estimates are still consistent in large samples; therefore we use the Driscoll-Kraay (1998) approach to correct standard errors in the FE model. By exploiting moment conditions to correct cross sectional dependence in a fashion proposed by Newy and West (1987), the Driscoll-Kraay approach eliminates the deficiencies of other feasible generalised least squares meth-

ods. Additionally, the Driscoll-Kraay covariance estimator is consistent for unknown forms of correlation, therefore we need not specify the structure of correlation (Hoechle, 2007). This feature of the Driscoll-Kraay estimator provides flexibility because it is very difficult to detect the form of spatial correlation in data. Furthermore, its asymptotic properties depend on time series dimension only, free from the order of cross sectional dimension.

As hypothesised, econometric results confirm a statistically significant nonlinear relationship between crop diversity and weather. We find level and squared terms of *kharif* rainfall statistically significant at the 10 per cent level with negative and positive signs respectively. It implies that specialisation in cropping pattern which started with the introduction of new technology will saturate due to the changing mean and/or or variance of rainfall. The changing summer monsoon is expected to increase diversification in the districts. Considering the fact that general circulation models still have difficulty to predict distribution of monsoon rainfall (Turner and Annamalai, 2012), the observed trend in rainfall indicates increasing variability in monsoon rainfall (Goswami *et al*., 2006; Rajeevan *et al*., 2008). Singh *et al*. (2014) observed increasing frequency of dry events and increasing intensity of wet events during the summer monsoon in India. Considering this evidence, increasing diversity in districts seems an adaptation measure by farmers in the state. The mean rainfall level at which the cropping pattern in districts will start diversifying turns out to be higher (approximately 188 mm) than the sample mean (132.9 mm); however, few districts in coastal region are very close to the turning point.

Of the two temperature variables, level and square terms of *rabi* temperature turn statistically significant at 5 per cent level with negative and positive signs respectively which infers that crop diversity in districts may increase with rising *rabi* temperature. Rising temperature increases crop water demand as well as irrigation demand. Both of these factors contribute to increasing production cost as well as risk in a bleak rainfall season (Table 3). A more evenly distributed crop portfolio, in which irrigation-intensive crops are mixed with drought tolerant crops, not only reduces production cost but also minimises production risk. Since the turning point of temperature (approximately 24ºC) based on the estimated coefficients turns very close to the mean *rabi* temperature; it can be said that crop diversity in the districts will increase with rising winter temperature.

We find a negative and statistically significant relationship between *kharif* dry days and diversification index which implies that more wet days during the *kharif* season are not conducive to crop specialisation. The sample mean of dry days in the *kharif* season is very low (Table 3). Too few rainless days reduces the window for effective application of fertilisers and pesticides, which affects yields negatively, especially in rice producing districts. Additionally, cotton, which is a major competing crop of rice in a few districts, requires weed removal for a higher yield. Weed removal is not possible in wet alluvial black soil regions of the state where most of the cotton fields lie (Jodha, 1977). Similarly, groundnut is the principal *kharif* crop in rainfall scarce southern region of Andhra Pradesh due to its drought tolerance (Table 2). The average number of rainfall days in this region is much lower than the state average. Therefore, more dry days than average leads to increased specialisation in different regions of the state for different reasons. In contrast, a statistically significant and positive relationship has been observed between *rabi* dry days and diversity index which implies that diversity increases when districts witness more dry days during the *rabi* season. Diversification is a rational strategy when faced with longer dry spells in a rainfall-scarce season. Cultivation of resource-intensive crops in a rainfall-scarce season is cost intensive and risky; therefore, it is justified that districts which witness more rainless days the during *rabi* season maintain more diversified cropping patterns.

Rainfall intensity has a positive and statistically significant impact on crop diversity in districts. The literature on monsoon rainfall pattern in India has shown that rainfall intensity is increasing (Goswami *et al*., 2006; Rajeevan *et al*., 2008; Dourte *et al*., 2013) which may lead to greater runoff. Too much or too little rainfall in few months of the year disrupt agricultural operations and causes damage to the sown area. Increasing diversity when faced with an uneven intra-annual distribution of rainfall, therefore, is indicative of farmers' response to rising weather risk.

The influence of economic factors, related with the development of agricultural infrastructure, on crop diversity is very strong and varied.[6] Labour per hectare is positively related to crop diversity indicating that cheap availability of labour incentivises farmers to diversify towards labour-intensive non-food grains. Irrigation reduces agricultural risk by increasing uniformity in soil moisture conditions throughout the year. A negative and significant relationship between irrigation share and crop diversity highlights this fact. Singh *et al*. (2006) observed a similar association between irrigation and crop diversity in a study of Indian states. A positive and statistically significant coefficient of cropping intensity highlights that crop choice differs across the seasons, i.e. farmers grow different crops during *rabi* and *kharif*. We find a positive relationship between diversity index and share of HYV area in total area.

Conclusion

We examined the relationship between crop diversity and climate change from the climate change adaptation perspective. On linking our econometric findings with crop area redistribution at regional level, it can be said that changing weather conditions influence crop diversity.

The results bring forth a few issues which may be useful from an adaptation perspective. Firstly, the specialisation pattern which evolved after a half century long adaptation of seed-water-fertiliser technology is changing and climate change is an important factor explaining it. In addition, cropping patterns in districts are sensitive to intra-annual distribution of rainfall and increasing rainfall intensity increased crop diversity. Additionally, the number of dry days across the seasons showed different impacts on crop diversity which implies that farmers respond differently to the frequency of

[6] We included road density and urban population share as a proxy for connectivity and market expansion; however, coefficients of these variables turned statistically insignificant.

rainfall events across seasons, therefore, season-specific adaptation planning is a better idea. Secondly, expenditure on agricultural research and intensification is instrumental to adaptation as the results show that increasing use of technological inputs such as HYV seeds and land augmentation has a positive influence on crop diversity. Thirdly, the declining share of pulses and oilseeds indicates a serious adaptation deficit. In addition, an increasing share of rice and other water- and resource-intensive crops in Andhra Pradesh may be a welcome sign as far as agricultural income is concerned, but the rice based cropping system is not sustainable in the long run. For example, the state has successfully relieved some pressure on the water and soil resources by redistributing the rice area across districts; however, rice cultivation has increased in inland districts which are water scarce. Any policy intervention meant to increase crop diversity will further boost adaptation if rice area can be substituted by dry land crops such as pulses and oilseeds. A seasonal pricing of electricity, credit and other inputs can be useful to increase diversity as well as to ensure sustainable intensification of agriculture in the state. Since rainfall is a scarce resource in most of the districts therefore, new irrigation techniques such as drip irrigation should be promoted to ensure agriculture sustainability in the state.

A nonlinear relationship between crop diversity and climate is sensitive to future changes in agricultural infrastructure and resource use. Any change in these factors may affect the estimation results. Another shortcoming of our approach is that it informs nothing regarding how the area of individual crops has changed over time. Therefore, an examination of the impact of climate change on crop area can be a possible extension of the present study.

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Shiferaw FELEKE*[1], Victor MANYONG*[2], Tahirou ABDOULAYE[3] and Arega D. ALENE***[4]**

Assessing the impacts of cassava technology on poverty reduction in Africa

In Africa, there have been successes in cassava research in terms of the development of production technologies, particularly improved varieties with high yield potential. The study addresses the question of whether and to what extent adoption of improved cassava varieties has led to rural poverty reduction in four African countries, namely Tanzania, Democratic Republic of Congo, Sierra Leone and Zambia. Data for the study come from a household survey conducted in the above-mentioned countries through a multinational-CGIAR support to agricultural research for development of strategic crops (SARD-SC) project in Africa. Given the observational nature of the data, a parametric approach (endogenous switching regression model) is applied. The results indicate that the model detects selectivity bias. Accounting for the bias, we find that adoption of cassava technology has resulted in an approximately 10 percentage point reduction in the poverty rate. Given an adoption rate of 34 per cent and a 10 percentage point reduction in the poverty rate, an estimated 24,309 households (equivalent to 194,469 individuals) have managed to move out of poverty in these four countries as a result of adoption of the technology. We also find that adoption of the technology has benefitted non-poor and female-headed households, relative to poor and male-headed households. The results present important evidence in favour of promoting cassava technology in a targeted fashion as part of an effective poverty reduction and sustained agricultural growth strategy in Africa. Considering the large realised and even more pronounced potential impacts of the adoption of cassava technology on poverty reduction, it is vital that regional and global development organisations should continue supporting the existing cassava improvement programme to sustain the technology development efforts in the continent.

Keywords: cassava varieties, households, adoption, selectivity bias, endogenous switching regression

* International Institute of Tropical Agriculture, Plot No. 25, Mikocheni Light Industrial Area, Mwenge-Coca Cola Road, P.O. Box 34441, Dar es Salaam, Tanzania. Corresponding author: s.feleke@cgiar.org
** International Institute of Tropical Agriculture, Ibadan, Nigeria
*** International Institute of Tropical Agriculture, Lilongwe, Malawi

Introduction

In Africa, there have been successes in agricultural research, particularly in cassava research in terms of the development of improved varieties with high yield potential. While agricultural research is arguably an effective driver of agricultural growth, Hazell and Haddad (2001) note that its benefits do not necessarily materialise for the poor nor do they all necessarily work in the same direction. This might be related to the fact that the poor assume non-exclusive roles in society at the same time (i.e. wage earners, consumers and producers). As wage earners, they may indirectly benefit from adoption due to labour market effects (an increase in wage rate and employment) as the technology becomes widely adopted, leading to an increase in market supply. They may also indirectly benefit from adoption as consumers due to product market or price effects as the increase in market supply leads to lower market prices. However, as the poor are also producers, the lower market prices may work against them, given that the demand for food in developing countries is price inelastic. The net impacts of agricultural research on the poor could thus be positive or negative depending on the circumstances under which they operate. However, in a study of the role of agricultural technology on world poverty using the computable general equilibrium (CGE) model, de Janvry and Sadoulet (2001) demonstrate that in Africa the direct effect of agricultural technology on poverty is the most important. This implies that agricultural research directly benefits the poor in Africa mainly if they are adopters. However, given that the poor are risk averse, constrained by lack of access to resources and information, they are less likely to adopt. Even when they are able to adopt, they do so late in the adoption life cycle in which case the benefits of the technology in terms of higher incomes may have already been erased because of the lower market prices. Therefore, assessing the actual impacts of adoption on the poor when they are able to do so, and the potential impacts of adoption on the current non-adopters should they be able to adopt is not trivial.

Seeking for evidence of the poverty impacts of the cassava research efforts, we address the question of whether and to what extent adoption of cassava technology has resulted in poverty reduction in four major cassava-producing African countries, namely Tanzania, Democratic Republic of Congo (DRC), Sierra Leone and Zambia. We also look into whether or not the impacts of adoption of the technology are more favourable towards poor versus non-poor, as well as male-headed versus female-headed households, or vice versa. Finally, we estimate the number of poor who have managed to move out of poverty as a result of adoption of the technology. The overall objective of the study is, therefore, to assess the causal effect of the adoption of cassava technology on poverty reduction. It is achieved by testing the null hypothesis that adoption of cassava technology in the study countries has not led to poverty reduction. Cassava technology in the present study refers to improved cassava varieties. Beyond establishing the causal link between adoption of cassava technology and poverty reduction, we estimate the number of poor lifted out of poverty due to adoption of the technology. To this end, we establish a procedure by which we assess the impacts

[1] http://orcid.org/0000-0002-0759-4070
[2] http://orcid.org/0000-0003-2477-7132
[3] http://orcid.org/0000-0002-8072-1363
[4] http://orcid.org/0000-0002-2491-4603

of adoption of the cassava technology on poverty reduction based on the results of the simultaneous estimation of the ESR model (i.e. a system of equations for adoption of cassava technology and per capita household expenditure). As far as we know, no study has estimated the number of poor lifted out of poverty due to the adoption of cassava technology, although a number of studies have done so for maize varieties. In a study on the economic and poverty impacts of maize research in West and Central Africa, Alene *et al*. (2009) estimated that over one million poor moved out of poverty annually since the mid-1990s. Most recently, Zeng *et al*. (2015) estimated that adoption of maize varieties has led to a 0.8–1.3 per cent poverty reduction, implying that up to 104,000 households in rural Ethiopia have escaped poverty.

The role of cassava research and policy support in Africa

Historically, cassava was a marginalised crop in Africa in the sense that it had not received as much attention as cereals from various stakeholders including policy makers and researchers. In fact, since most cassava producers are poor smallholders, it was regarded as 'food of the poor' (Rosenthal and Ort, 2011). However, following the realisation of its role against hunger during recurrent droughts, particularly the severe drought of 1982-83, it has started receiving more attention from both policy makers and researchers. For example, in East and Southern Africa, farmers were encouraged to have a piece of land under cassava (Alene *et al*., 2013). In the meantime, cassava research has been strengthened, leading to the development of improved production and processing technologies. The International Institute of Tropical Agriculture (IITA), in partnership with the respective national cassava research programmes of various African countries, has developed a number of improved cassava varieties that combine multiple pest and disease resistances with superior post-harvest qualities and yield potential (Nweke, 2004). More than 40 improved cassava varieties have been developed over the last 45 years (IITA, 2013). Most of these varieties have successfully been promoted to cassava farmers by national extension services and non-governmental institutions under different collaborative project initiatives and programmes. Among such initiatives is the USAID/IITA multi-country project (unleashing the power of cassava) which has helped to disseminate the varieties in countries such as Ghana, Malawi, Mozambique, Nigeria, Sierra Leone, DRC and Tanzania. These efforts have led to higher yield, shorter maturity period and higher tolerance to diseases such as Cassava Mosaic Disease and Brown Streak Disease. In Malawi, for example, adoption of cassava technology has boosted cassava production, contributing to measurable gains in household calorie intake (Rusike *et al*., 2010). In DRC, it has enhanced household food adequacy (Rusike *et al*., 2014).

Given the policy and research support it has received over the past few decades, cassava is being transformed into one of the most important enterprises in Africa. A number of industrial products such as high quality flour and starch are currently produced from cassava. There have been on-going efforts to create strong linkages among cassava value chain actors and partnerships with the private sector, which has a vested interest in the quality of the cassava crop for industrial uses. Private companies multiply and distribute planting materials of improved varieties (FAO/IFAD, 2005). As the uses of industrial cassava continue to increase in Africa, the private sector demands not only more output but also higher quality, which will be dictated by the type of varieties to be cultivated, and production and post-harvest management practices to be applied. Demand for cassava is already on the rise, leading to increased production. Food and Agriculture Organization (FAO) data from 2000 to 2013 show that about 60 per cent of the increases in global cassava production occurred in Africa. There is now more cassava produced in Africa than the rest of the world combined, with the leading producers in the continent being Nigeria, DRC, Ghana, Tanzania and Mozambique. By 2020 over 60 per cent of the global cassava production is expected to be in Africa (FAO/IFAD, 2005). In terms of consumption, cassava is now the second most important crop after maize, contributing over 40 per cent of the food calories consumed in Africa and supporting over 200 million people in the continent as a major staple food crop (Enete, 2009; Yidana and Amadu, 2013). In the DRC, it accounts for more than half of the daily calorie consumption per capita, providing the cheapest and most readily available food when compared with other close substitutes such as maize. Its role is even more pronounced during dry seasons, serving as the last line of defence against hunger. Given its unique and significant contribution to the livelihoods of African farmers, and its potential for transforming the African economies, cassava is among the six commodities defined by the African Heads of States as strategic crops for Africa.

Methodology

Empirical model

As the sample households were not randomly assigned to treatment and control groups during the dissemination of the cassava technology, isolating the poverty impacts of adoption of the technology is challenging. In the absence of random assignment, the decision between adoption and non-adoption could be influenced by observed and unobserved household characteristics. That is, households would self-select themselves either *into* adoption or *out of* adoption depending on their observed and unobserved characteristics. Past empirical studies have attempted to address such a challenge using a number of parametric and non-parametric approaches (Asfaw *et al*., 2012; Khonje *et al*., 2014; Shiferaw *et al*., 2014). The most common ones include propensity score matching (PSM) and endogenous switching regression model (ESR). While the PSM approach creates a condition that mimics a randomised experiment based on the conditional independence assumption and allows the estimation of causal effects, it is limited by the fact that the experimental condition is created based on measured

characteristics. This leaves the analyst with no choice but to assume that no unmeasured characteristics exist that affect both the treatment and outcome variables. As a result, most analysts resort to parametric approaches such as the ESR model that takes into account both the measured and unmeasured attributes in estimation of treatment impacts. The present study applies the ESR approach in view of its capability in taking account of unobserved heterogeneities, thereby providing unbiased and consistent parameter estimates upon which the assessment of the causal effects is based.

The ESR model consists of one treatment selection equation and two separate outcome equations conditional on the selection criterion. In the present study, the treatment variable is adoption while the outcome variable is household expenditure. Thus, the selection equation refers to the adoption decision on cassava technology and there are two expenditure equations conditional on adoption.

The adoption equation can be specified as:

$$A_i^* = \gamma Z_i + u_i, i = 0, 1 \tag{1}$$

where A_i^* is the latent variable indexing the propensity of adoption with i taking 1 for the status of adoption and 0 for that of non-adoption; Z_i is a vector of exogenous variables influencing adoption; γ is a vector of parameters to be estimated; u_i is the error term associated with adoption.

Assuming that a given household decides adopting cassava technology if the expected utility from adoption outweighs that of non-adoption or decides against adoption, the adoption criterion can be given as:

$$\begin{cases} A_i = 1 \ \ if \ A_1^* > A_0^* \\ A_i = 0 \ \ otherwise \end{cases} \tag{2}$$

Also, assuming a standard normal distribution for the error term, equation 1 is cast as a probit model.

With regard to the household expenditure equation, we follow the modelling of the production and consumption behaviours of a rural household by Straus (1983) and specify household expenditure as a function of consumption-side and production-side variables within the framework of consumer demand and production theories. We assume separability between production and consumption decisions, which are recursive in the sense that production decisions are made first and subsequently used in allocating the full income for consumption of goods.

The two linear expenditure equations, conditional on the adoption criterion, can be specified as below where households face two regimes (1) adoption, and (2) non-adoption:

$$\begin{aligned} &\text{Regime 1} \ \ Y_{1i} = \beta_1 X_{1i} + \varepsilon_{1i} \ \ \ if \ \ A_i = 1 \\ &\text{Regime 2} \ \ Y_{2i} = \beta_2 X_{2i} + \varepsilon_{2i} \ \ \ if \ \ A_i = 0 \end{aligned} \tag{3}$$

where Y_{1i} and Y_{2i} are daily per capita expenditures observed for each household depending on the adoption criterion; X_i represents a vector of exogenous variables that affect expenditure; β is a vector of parameters to be estimated; ε_{1i} and ε_{2i} are the error terms associated with the two expenditure equations.

The error terms are assumed to have a tri-variate normal distribution with zero mean and non-singular covariance matrix (Maddala, 1983) given as:

$$\text{cov}(u, \varepsilon_1, \varepsilon_2) = \begin{bmatrix} \sigma_u^2 & \sigma_{u\varepsilon_1} & \sigma_{u\varepsilon_2} \\ \sigma_{\varepsilon_1 u} & \sigma_{\varepsilon_1}^2 & \cdot \\ \sigma_{\varepsilon_2 u} & \cdot & \sigma_{\varepsilon_2}^2 \end{bmatrix} \tag{4}$$

where σ_u^2 is variance of the error term in the adoption equation which is assumed to be 1; $\sigma_{\varepsilon_1}^2$ and $\sigma_{\varepsilon_2}^2$ are variances of the error terms in the expenditure equations; $\sigma_{u\varepsilon_1}$ and $\sigma_{u\varepsilon_2}$ are covariances of the error terms between the adoption equation and the expenditure equations.

The covariances between the error terms in the expenditure equations are undefined since the daily per capita expenditures Y_{1i} and Y_{2i} are not observed simultaneously. The expected values of the error terms, ε_1 and ε_2, conditional on the adoption criterion, are non-zero because of the possible correlation between the error term in the adoption equation and the error terms of the expenditure equations:

$$E(\varepsilon_{i1} | A_i = 1) = \sigma_{u\varepsilon_1} \frac{\phi(\hat{A})}{\Phi(\hat{A})} \tag{5a}$$

$$E(\varepsilon_{i2} | A_i = 0) = -\sigma_{u\varepsilon_2} \frac{\phi(\hat{A})}{1 - \Phi(\hat{A})} \tag{5b}$$

where $\phi(.)$ is the standard normal probability density function, $\Phi(.)$ is the standard normal cumulative function; $\frac{\phi(\hat{A})}{\Phi(\hat{A})}$ and $\frac{\phi(\hat{A})}{1 - \Phi(\hat{A})}$ are the inverse Mill's ratio evaluated at $\hat{A} = Z_i\gamma$ in the adoption equation where $\hat{A}$ is the predicted probability of adoption, A_i.

As the ESR model addresses the issue of selection bias as a missing variable problem, the inverse Mills ratio terms from the probit adoption model are added into the expenditure equations to correct for the potential selection bias as:

$$Y_{1i} = \beta X_{1i} + \sigma_{u\varepsilon_1} \frac{\phi(\hat{A})}{\Phi(\hat{A})} + \epsilon_{1i} \ \ if \ A_i = 1 \tag{6a}$$

$$Y_{2i} = \beta X_{2i} + \sigma_{u\varepsilon_2} \frac{\phi(\hat{A})}{1 - \Phi(\hat{A})} + \epsilon_{2i} \ \ if \ A_i = 0 \tag{6b}$$

If the $\sigma_{u\varepsilon_1}$ and $\sigma_{u\varepsilon_2}$ are statistically significant, switching is endogenous. Otherwise, switching is exogenous. The above equations can be estimated in a two-stage procedure. However, the efficient way to estimate them is by full information maximum likelihood estimator (FIML) (Lokshin and Sajaia, 2004).

Assessing the impacts of adoption on poverty reduction

In this study, we assess both the actual and potential impacts of adoption of cassava technology on poverty reduction. Actual impacts refer to the actual gain in incomes (proxied by expenditure) and associated actual reduction of poverty among the current adopters while potential impacts refer to the potential gain in incomes and associated potential

reduction of poverty among the current non-adopters, considering them as potential adopters should they choose and be able to adopt cassava technology.

Both the actual and potential impacts of adoption on poverty reduction are assessed based on the parameter estimates of the ESR model that consists of the system of one adoption equation of cassava technology and two expenditure equations. For both the actual and potential impacts, we firstly estimate the ESR model using the FIML estimator, and then generate distributions of expected daily per capita expenditures under observed and counterfactual conditions. For adopters, we generate two distributions under observed (with adoption) and counterfactual (without adoption, i.e. had they not adopted) using equation 7a and equation 7b given, respectively, as:

$$E(Y_{1i}|A_i = 1) = X_{1i}\beta_1 + \sigma_{\varepsilon_1 u}\frac{\phi(\hat{A})}{\Phi(\hat{A})} \tag{7a}$$

$$E(Y_{2i}|A_i = 1) = X_{1i}\beta_2 + \sigma_{\varepsilon_2 u}\frac{\phi(\hat{A})}{\Phi(\hat{A})} \tag{7b}$$

Based on the two distributions generated using equations 7a and 7b, we compute the average daily per capita expenditure and the three indices of poverty (poverty headcount index, poverty gap index and poverty gap-squared index) separately for each distribution. The difference in the respective average daily per capita expenditure and indices of poverty between the observed (with adoption) and counterfactual (without adoption) distributions for adopters will provide the actual impacts of adoption in terms of the actual increase in average daily per capita expenditure and associated actual reduction in the indices of poverty.

Analogously, for non-adopters, we generate two distributions under observed (without adoption) and counterfactual (with adoption, i.e. had they adopted) using equation 7c and equation 7d given, respectively, as:

$$E(Y_{2i}|A_i = 0) = X_{2i}\beta_2 + \sigma_{\varepsilon_2 u}\frac{\phi(\hat{A})}{1 - \Phi(\hat{A})} \tag{7c}$$

$$E(Y_{1i}|A_i = 0) = X_{2i}\beta_1 + \sigma_{\varepsilon_1 u}\frac{\phi(\hat{A})}{1 - \Phi(\hat{A})} \tag{7d}$$

Based on the two distributions generated using equations 7c and 7d, we compute the average daily per capita expenditure and the three indices of poverty described above. The difference in the respective average daily per capita expenditure and indices of poverty between the observed (without adoption) and counterfactual (with adoption) distributions for non-adopters provides the potential impacts of adoption in terms of the potential increase in average daily per capita expenditure and associated potential reduction in the indices of poverty.

Data and measurement of model variables

The data for this study came from a formal household survey conducted in four major cassava-producing countries, namely Tanzania, DRC, Sierra Leone and Zambia. Both non-random and random sampling methods were applied in the selection of the sample households. The non-random selection was applied to identify districts that have high potential for cassava production. Once the districts were selected, a two-stage random sampling was applied. The first stage involved the selection of villages and the second stage involved the selection of sample households. The standardised questionnaire included sections on household demographic, biophysical, socio-economic and institutional characteristics. The study has one treatment variable, thirteen independent variables and four outcome variables (Table 1). The treatment variable is adoption, which was measured based on whether or not the household cultivated one or more improved cassava varieties in 2013. The independent variables are a set of demographic, biophysical, socioeconomic and institutional characteristics of the study households. The choice of these variables is driven by economic theory of the production and consumption behaviours of a rural household and knowledge of similar previous research. The four outcome variables are daily per capita expenditure, and the three Foster, Greer and Thorbecke (FGT) indices of poverty (headcount index, poverty gap index and poverty gap-squared index).

Although poverty has multiple dimensions, it was measured in this study based on its monetary dimension of consumption expenditure. As consumption is considered not only a better outcome indicator but also may be better measured than income, expenditure is chosen for measuring poverty based on FGT indices as presented in Haughton and Khandker (2009). The consumption expenditure is constituted from two components – food consumption expenditure and non-food consumption expenditure. Data on consumed quantities of the list of food items differentiated by source (own production, purchase, gifts, borrowing and food aids) over the past one week preceding the survey were collected. Both quantities and prices were obtained for each food item reported to have been purchased and consumed over the given period of time. Reported prices for purchased food were applied to compute the imputed value of home-produced food and food items acquired through gifts, borrowing and food aids. Data on non-food consumption were similarly collected by asking the list of non-food items with the respective quantities and prices over the past one month preceding the survey. The food and non-food expenditures over the two given periods were respectively adjusted to daily food and non-food expenditure level. They were then converted to USD by the purchasing power parity (PPP) exchange rate of the respective country and aggregated to daily household expenditure for each sample household. Finally, the daily per capita household expenditure adjusted for the PPP was used in the analysis. An individual is considered to live in extreme poverty if he or she subsists on an average of USD 1.25 or less a day adjusted for the PPP. This is the poverty line. The headcount index measures the poverty rate, which is the proportion of people living below the poverty line. The poverty gap index measures the depth of poverty, which is the extent of income shortfall from the poverty line. The poverty gap-squared index measures the severity of poverty that indicates the degree of income inequality among the poor themselves.

Table 1: Description of treatment, independent and outcome variables.

Variable	Code	Description
Treatment variable		
Adoption	Adoption	Adoption = 1 if the household cultivated one or more improved cassava varieties in 2013; otherwise Adoption = 0
Outcome variables		
Daily per capita expenditure	Daily per capita expenditure	Household expenditure measured in USD per capita per day adjusted for purchasing power parity
Poverty headcount index	Poverty head-count index	The poverty headcount index measures the poverty rate, which is the proportion of people living below the poverty line
Poverty gap index	Poverty gap index	The poverty gap index measures the depth of poverty, which is the extent of income shortfall from the poverty line
Poverty gap-squared index	Poverty gap-squared index	The poverty gap-squared index measures the severity of poverty that indicates the degree of income inequality among the poor themselves
Demographic independent variables		
Gender	Gender	Gender = 1 if the head of the household is male; otherwise Gender = 0
Age	Age	Age1 = 1 if age of the head of the household is below 30 years; otherwise Age1 = 0 Age2 = 1 if age of the head of the household is between 30 and 65 years; otherwise Age2 = 0 Age3 = 1 if age of the head of the household is 65 years and above; otherwise Age3 = 0
Education	Education	Education = 1 if the head of the household has some formal education; otherwise Education = 0
Primary occupation	Occupation	Occupation = 1 if the primary occupation of the household is crop and livestock production; otherwise Occupation = 0
Socioeconomic independent variables		
Cultivated cassava land	Cultivated	Number of acres dedicated to cassava production
Labour	Labour	Number of family members working on own farm, including the operator of the farm
Household type	Subsistent	Subsistent = 1 if more than 50 per cent of the household's cassava production is devoted for home consumption; otherwise Subsistent = 0
Biophysical independent variables		
Cassava cropping system	System	System = 1 if the household is practicing mono-cropping; System = 0 if the household is practicing cassava mixed cropping system with other crops
Institutional independent variables		
Access to planting materials in the vicinity	Seeds	Seeds = 1 if the household has access to planting materials in their villages; otherwise Seeds = 0
Access to extension	Extension	Extension = 1 if the household was visited by an extension agent in the past year; otherwise Extension = 0
Access to credit	Credit	Credit = 1 if the household received loan for purchase of cassava planting materials and fertilisers in the past year; otherwise Credit = 0
Membership to local associations	Membership	Membership = 1 if the household belongs to a local farm association; otherwise Membership = 0
Country	TZ	TZ = 1 if the household is from Tanzania; otherwise TZ = 0
	DRC	DRC = 1 if the household is from DRC; otherwise DRC = 0
	SL	SL = 1 if the household is from Sierra Leone; otherwise SL = 0
	ZA	ZA = 1 if the household is from Zambia; otherwise ZA = 0

Source: own composition

Results and discussion

The results from the descriptive analysis establish the empirical relationship between adoption and individual household characteristics and outcome variables. The results from the multivariate analysis include the estimates of the actual and differential income effects of the adoption of cassava technology on the poor *vis-a-vis* the non-poor, as well as on the female-headed *vis-a-vis* the male-headed households, the estimates of the number of poor lifted out of poverty due to adoption, the potential impacts on poverty reduction should the current non-adopters be able to adopt cassava technology, and the barriers to adoption of this technology.

Descriptive results

Table 2 presents the descriptive statistics of the treatment, outcome and explanatory variables included in the model. The rate of adoption as defined by the proportion of households who reported to have planted one or more improved cassava varieties in 2013 is 34 per cent. The majority of the household characteristics are significantly different between adopters and non-adopters. For example, a relatively larger proportion of adopters have access to extension, planting materials (denoted by seeds) and credit services. About 33 per cent of adopters are visited by extension agents, compared to only 22 per cent of non-adopters. Analogously, about 30 per cent of adopters reported to have access to planting materials, compared to only 17 per cent of non-adopters.

As for the relationship between adoption and outcome variables, a straightforward comparison between adopters and non-adopters shows that adopters have relatively higher daily per capita expenditure than non-adopters (Table 3). Further, the rate, depth and severity of poverty are lower among adopters than non-adopters. The headcount ratio for adopters is about 45 per cent, compared to about 50 per cent for non-adopters. Analogously, adopters have relatively smaller poverty gap (indicator of income shortfall from poverty line) and poverty gap-squared (indicator of degree of inequality

Table 2: Descriptive statistics of the treatment and independent variables.

Variable	Level	Non-adopters	Adopters	Pooled sample
Adoption	Number of obs.	1273	646	1919
Gender	Male=1	0.865	0.850	0.860
	Age1	0.086	0.082	0.085
Age	Age2	0.802	0.819	0.808
	Age3	0.111	0.099	0.107
Education	Formal=1	0.747	0.716	0.737
Occupation	Agriculture	0.948	0.920	0.939
Subsistent	Subsistent=1	0.456	0.356	0.422
Cultivated	Ha	1.7	2.9	2.1
Labour	Number	3.8	4.6	4.1
System	Mono cropping=1	0.374	0.371	0.373
Seeds	Yes=1	0.166	0.300	0.210
Extension	Yes=1	0.216	0.327	0.253
Credit	Yes=1	0.033	0.075	0.047
Membership	Yes=1	0.541	0.551	0.544
TZ	Yes=1	0.312	0.306	0.310
DRC	Yes=1	0.134	0.217	0.162
SL	Yes=1	0.235	0.367	0.279
ZA	Yes=1	0.319	0.110	0.249

For details of variables see Table 1
Source: own calculations

Table 3: Descriptive statistics of outcome variables.

Outcome variable	Non-adopters	Adopters	Pooled sample
Daily per capita expenditure (USD)	1.93 (2.85)	2.01 (2.90)	1.95 (2.62)
Poverty headcount index	0.504	0.446	0.485
Poverty gap index	0.220 (0.279)	0.171 (0.253)	0.204 (0.271)
Poverty gap-squared index	0.126 (0.203)	0.093 (0.177)	0.115 (0.195)

Figures in parenthesis are standard deviations
Source: own calculations

among the poor) than non-adopters. On average, adopters have a poverty gap of 17 per cent compared to 22 per cent for non-adopters. Since these results are generated without taking account of the effects of other observed and unobserved household characteristics, they have no causal interpretation. In such a situation, adopters and non-adopters will not be truly comparable with respect to the poverty outcome variables that we are intending to evaluate in this study. This is because the differences in the outcome variables between adopters and non-adopters might be not because of adoption but because of the difference in the uncontrolled observed characteristics and unobservables. The next section provides the results of the multivariate analysis conducted using the ESR model. Since the ESR model controls for observed characteristics and takes account of unobserved heterogeneities, the parameter estimates of the ESR model that are used in the estimation of causal effects of adoption are unbiased and consistent.

Results from multivariate analysis

Table 4 presents the results from the multivariate analysis (the ESR model) implemented in STATA using the *movestay* command (Lokshin and Sajaia, 2004). The likelihood ratio test rejects the null hypothesis of joint independence [$\chi 2$ (1) =786.5; p=0.000]. This provides evidence of appropriateness of the assumption that effects of covariates across the two groups – adopters and non-adopters – are significantly different. Hence, we have two distinct regression equations or regimes rather than one. In addition, the model detects selectivity bias. This implies that the decision into adoption and non-adoption of cassava technology is likely based on unobservables (e.g. risk-taking behaviour) that correlate with the outcome variable (i.e. expendi-

Table 4: FIML estimates of the ESR model of per capita expenditure.

Variable	Selection/adoption equation		Outcome/expenditure equations			
			Regime 1 (adoption)		Regime 2 (non-adoption)	
	Estimate	SE	Estimate	SE	Estimate	SE
Gender	-0.277**	0.115	-0.050	0.111	0.142*	0.080
Age2	-0.119	0.142	-0.152	0.136	-0.165*	0.100
Age3	-0.012	0.176	-0.259	0.169	-0.312***	0.122
Education	0.346***	0.120	-0.015	0.118	0.125	0.085
Subsistent	-0.183**	0.078	-0.033	0.076	-0.034	0.054
Cultivated	0.050**	0.021	-0.002	0.013	0.015	0.017
Labour	0.051***	0.019	-0.066***	0.020	-0.043	0.014
Occupation	-0.217	0.153				
System	0.294***	0.091				
Seeds	0.391***	0.097				
Credit	0.370**	0.167				
Membership	0.142*	0.086				
Extension	0.465***	0.092				
TZ	0.724***	0.114	0.388***	0.145	0.596***	0.073
DRC	1.211***	0.127	-0.411***	0.157	0.188*	0.099
SL	1.233***	0.173	0.315*	0.193	0.636***	0.146
Constant	-1.470***	0.275	0.989***	0.333	-0.058	0.144
Sigma(σ_j)			0.768***	0.040	0.778***	0.019
σ_j			-0.25		-0.08	
Rho(ρ_j)			-0.320*	0.175	-0.100	0.170

LR test of independent equations: $\chi^2(1)=786.5$; $p=0.000$; for details of variables see Table 1
*, ** and *** denote, respectively, significance level at 10%, 5%, and 1%
Source: own calculations

ture). With the covariances between the error terms of the adoption equation and the expenditure equations for both adopters and non-adopters being negative, we have a case of negative selection *into* and *out of* adoption. The current adopters are likely to have self-selected themselves *into* adoption precipitated by expected benefits from adoption of cassava technology in terms of increased consumption expenditure. Similarly, the current non-adopters are likely to have self-selected themselves *out of* adoption because they may not have expected to benefit from adoption. The current adopters had they not adopted would have done worse than the current non-adopters. In contrast, the current non-adopters had they adopted would have done better than the current adopters. These can be readily seen in the estimates of the expected daily per capita expenditure under observed and counterfactual conditions as suggested by Maddala (1986)[5]. The average daily per capita expenditure of the current adopters had they not adopted would have been USD 1.23, compared to USD 1.26 observed for the current non-adopters (Tables 5 and 6). That is, the current adopters had they not adopted would have an average daily per capita expenditure of USD 0.03 less than what the current non-adopters are actually observed to have. In the same Tables, it can also be seen that the average daily per capita expenditure of the current non-adopters had they adopted would have been USD 2.19, compared to USD 1.52 observed for the current adopters. That is, the current non-adopters had they adopted would have USD 0.67 more daily per capita expenditure than what the current adopters are currently having.

Actual impacts of adoption

The results indicate that adoption resulted in a USD 0.29 increase in daily per capita expenditure (USD 1.52 cf. USD 1.23, Table 5). About 44 per cent of adopters are below the poverty line but, had it not been for adoption, the poverty rate would have been about 54 per cent. This suggests that the USD 0.29 gain in average daily per capita expenditure due to adoption of cassava technology has led to an approximately 10 percentage point reduction in poverty (Table 5). It also yielded a 3 percentage point reduction in depth of poverty, translating into a per capita cost savings of USD 11 per year. Drawing on the estimates of the gain in average daily per capita income (as proxied by the average daily per capita expenditure) and associated reduction in the respective indices of poverty reported in Table 5, a 1 per cent increase in daily per capita expenditure due to adoption is associated with a 0.8, 1.03 and 1.56 per cent reduction in rate, depth and severity of poverty respectively. While the results are consistent that adoption of cassava technology has a poverty-reducing impact at the USD 1.25 per capita per day poverty line, there is no guarantee that they would hold at different poverty lines. The following section presents the sensitivity of the poverty-reducing impacts of the adoption of cassava technology to different poverty lines.

[5] In addition to the sign and magnitude of the covariances that depict the direction and degree of non-random selection, it is important to estimate the mean values of the dependent variables for the alternate choice because they shed light on the effects of self-selection (Maddala, 1986).

Table 5: Average effects on adopters.

Outcome variable	Decision stage		Average effect
	Adopt	Not to adopt	
Daily per capita expenditure (USD)	1.52	1.23	0.29 (0.015)***
Headcount index	0.443	0.547	-0.103 (0.034)***
Poverty gap index	0.093	0.123	-0.030 (0.006)***
Poverty gap squared index	0.024	0.038	-0.014 (0.003)***

*** denotes statistical significance at 1%; figures in parenthesis are standard errors
Source: own calculations

Table 6: Average effects on non-adopters.

Outcome variable	Decision stage		Average effects
	Adopt	Not to adopt	
Daily per capita expenditure (USD)	2.19	1.26	0.93 (0.014)***
Poverty headcount index	0.044	0.567	-0.523 (0.016)***
Poverty gap index	0.005	0.140	-0.135 (0.005)***
Poverty gap-squared index	0.001	0.043	-0.042 (0.002)***

*** denotes statistical significance at 1%; figures in parenthesis are standard errors

Source: own calculations

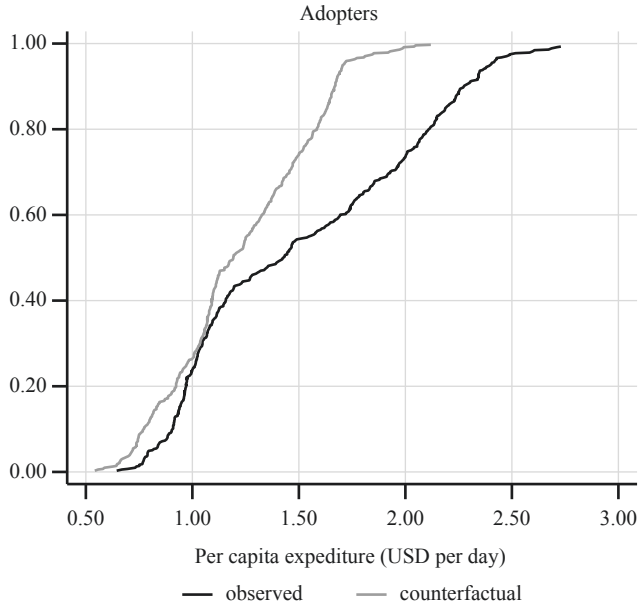

Figure 1: Observed and counterfactual cumulative distribution.
Source: own composition

Sensitivity of results to different poverty lines

To check the effect of different poverty lines on poverty, we look at the entire distribution using the theory of stochastic dominance. The distribution of the observed daily per capita expenditure for adopters lies predominantly to the right of the counterfactual as high as the USD 2.25 poverty line (Figure 1). Now, the question is whether the USD 2.25 per day poverty line is such that all conceivable poverty lines are below it. Given that almost all of the individuals are below the poverty line of USD 2.25 per capita per day, intersection of the two distributions is unlikely beyond USD 2.25 per day. This is confirmed using the Kolmogorov–Smirnov statistic for first degree stochastic dominance, rejecting the hypothesis that the two distributions are the same.

Impacts of adoption on female-headed vis-a-vis male-headed households

Table 7 reports the poverty-reducing impacts of adoption disaggregated by type of household, revealing that adoption has greater income effects and associated poverty-reducing impacts among female-headed households than among male-headed households. The former are observed to have an average daily per capita expenditure of USD 1.69. But, had they not adopted, they would have an average daily per capita expenditure of USD 1.08, implying that they gained USD 0.62 compared to USD 0.23 gained by the latter. As a result, the rate poverty among female-headed households is 15 percentage points lower than among male-headed households. The difference in both daily per capita expenditure and poverty rate between the two groups is statistically significant. The female-headed households have also performed better in terms of both the depth and severity of poverty. This is not unexpected given that female-headed households are more likely than male-headed households to adopt cassava technology. This implies that, controlling for the observable and unobservable heterogeneities in household characteristics, female-headed households are not disadvantaged relative to male-headed households when it comes to cassava technology.

Impacts of adoption on the poor vs. the non-poor

To assess the differential impacts of adoption on the poor *vis-à-vis* the non-poor, we decompose the overall increase in average daily per capita expenditure. The average observed daily per capita expenditure for adopters is USD 1.52, compared to USD 1.23 had they not adopted, yielding a 23 per cent gain which is decomposed as:

$$(G/E_c)\% = \beta(G_p/E_{c,p})\% + (1-\beta)(G_n/E_{c,n})\% \quad (8)$$

where $(G/E_c)\%$ is the overall average gain as a percentage of the counterfactual daily per capita expenditure (c) for the whole sample; β is the expenditure share of the poor in total expenditure; $(G_p/E_{c,p})\%$ is the average gain as a percentage of the counterfactual daily per capita expenditure (c) for the poor (p); $(G_n/E_{c,n})\%$ is the average gain as a percentage of the counterfactual daily per capita expenditure (c) for the non-poor (n). The first term on the right side of equation 8 provides the share of the gain that accrues to the poor while the second term provides the share of the gain that accrues to the non-poor.

In the light of equation 8, the 23 per cent overall average gain due to adoption is decomposed such that 5 per cent would accrue to the poor, compared to 18 per cent that would accrue to the non-poor (Table 8). In other words, of the USD 0.29 gain due to adoption, USD 0.23 accrues to the non-poor, and USD 0.06 accrues to the poor group.

Number of poor lifted out of poverty due to cassava technology

Beyond establishing causality between adoption and poverty, we have also estimated the number of households who have managed to overcome poverty as a result of the adoption of cassava technology. Firstly, we estimate the population of adopting households. Secondly, we apply the FGT headcount indices of poverty computed separately

Table 7: Poverty-reducing impacts of adoption disaggregated by type of household.

Outcome variable	Head of household (HH)	Decision stage		Average effects	Difference in average effects between male-headed and female-headed HH
		Adopt	Not to adopt		
Daily per capita expenditure (USD)	Female	1.69	1.08	0.600 (0.043)	0.37 (0.041) ***
	Male	1.49	1.26	0.230 (0.015)	
Poverty headcount index	Female	0.373	0.610	-0.237 (0.056)	-0.155 (0.046) ***
	Male	0.455	0.537	-0.082 (0.016)	
Poverty gap index	Female	0.052	0.181	-0.129 (0.021)	-0.114 (0.016) ***
	Male	0.100	0.114	-0.014 (0.005)	
Poverty gap-squared index	Female	0.010	0.069	-0.059 (0.011)	-0.053 (0.008)***
	Male	0.026	0.033	-0.007 (0.003)	

*** denotes significance at 1% level; numbers in parentheses are standard errors
Source: own calculations

Table 8: Differential impacts of adoption on the poor vs. non-poor in daily per capita expenditure (USD).

Group	Decision stage		Average gain as a percentage of the counterfactual	Expenditure share (%)	Share of overall average gain (%)
	Adopt	Not to adopt			
All	1.52	1.23	23.6		
Non-poor	2.05	1.56	31.4	57.0	17.9
Poor	1.09	0.97	12.4	43.0	5.3

Non-poor refers to the group of adopters who are above the poverty line with and without adoption; *poor* refers to those who are below the poverty line without adoption; some of them have moved out of poverty with adoption while some others remain poor despite adoption
Source: own calculations

from the observed and counterfactual distributions to the estimated population of adopting households and calculate the population of poor households (observed) as well as the population of households who would have been poor had it not been for adoption (counterfactual). Thirdly, we take the difference between the two estimated population figures, yielding the poverty impacts of adoption expressed in terms of the number of households who managed to overcome poverty.

Given an adoption rate of 34 per cent, 236,006 out of the total estimated 694,135 cassava-producing households in the study districts are considered to have adopted one or more improved cassava varieties in 2013. In the same year, 44.4 per cent of these households (equivalent to 104,787 households) are observed to be below the poverty line. Had it not been for adoption, the poverty rate would have ticked 10.3 percentage points, rising to 54.7 per cent. This means that there would be 129,095 poor households without adoption. This implies that an estimated 24,309 households (equivalent to 194,469 individuals estimated at eight persons per household) have managed to move out of poverty.

Potential impacts of adoption

Potential impacts refer to potential benefits that may accrue to the current non-adopters should they choose to adopt the cassava technology in the future. An approach similar to the one applied for the assessment of the actual impacts is applied, considering the current non-adopters as potential adopters. A comparison of the actual versus the potential impacts of adoption shows that the latter (Table 6) is greater than the former (Table 5). This is apparent in Figures 1 and 2 where the size of the gap between the observed and counterfactual curves in Figure 2 (potential impacts) is larger than the case in Figure 1 (actual impacts). Non-adopters are observed to have an average daily per capita expenditure of USD 1.26. But, had they adopted, they would have an average daily per capita expenditure of USD 2.19, yielding an additional gain of USD 0.93. Drawing on the potential gain in average daily per capita expenditure and associated potential reduction in the poverty rate reported in Table 6, it is established that a 1 per cent increase in daily per capita expenditure due to adoption is associated with a 1.25 per cent potential reduction in the poverty rate among current non-adopters, compared to 0.8 per cent actual reduction among current adopters. Current non-adopters would also potentially fare better than the current adopters in terms of depth of poverty. A 1 per cent increase in daily per capita expenditure due to adoption is associated with a 1.31 per cent potential reduction in depth of poverty among current non-adopters, compared to 1.03 per cent actual reduction among current adopters. These results suggest that it is important to address the barriers to adoption in order that the current non-adopters can take up the cassava technology.

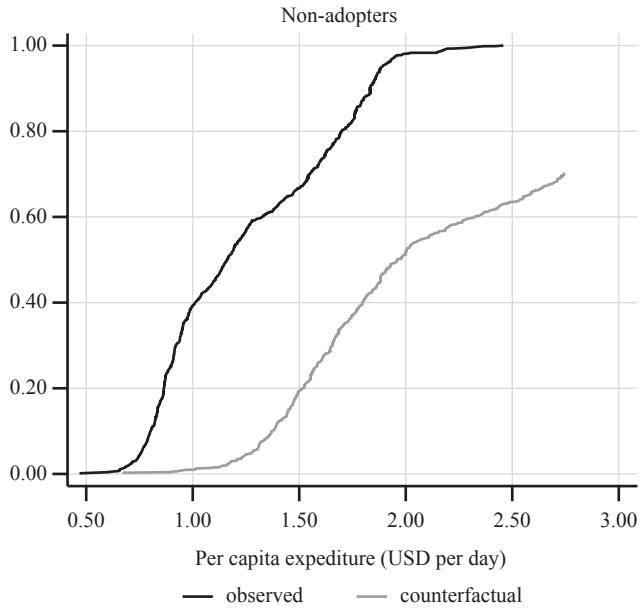

Figure 2: Observed and counterfactual cumulative distribution.
Source: own composition

Barriers to adoption

In order to identify the barriers to adoption, we rely on the parameter estimates of the selection or adoption equation of the ESR model in Table 4. The major barriers to adoption are identified as lack of access to extension, planting materials, credit, formal education and limited availability of resources (labour force and cassava farm area). Gender and education level of the head of the household are found to have statistically significant effects on adoption of improved cassava varieties. The probability of adopting cassava technology is lower for male-headed households than female-headed households. Consistent with expectation, education is positively related to adoption of cassava technology, indicating that households with a formal education are more likely to adopt cassava technology than those households without. Labour force and cassava farm area are also found to be statistically significant between adopters and non-adopters. In terms of biophysical characteristics, the type of cassava cropping system has a statistically significant relationship with adoption. Households who practice a mono cassava cropping system are more likely to adopt improved cassava varieties than those who practice a mixed cropping system. As regards the institutional characteristics, access to planting materials, access to extension services and credit services are found to significantly influence adoption. Households with access to planting materials, extension visits and credit are more likely to adopt improved cassava varieties.

Conclusion and implications

The study assesses the actual and potential impacts of adoption of cassava technology on poverty reduction in four African countries. Unlike many past impact assessment studies, it goes beyond establishing the causal link between adoption of technology and poverty reduction and estimates the number of poor lifted out of poverty. The study also assesses the differential impacts of adoption on the poor vs. the non-poor, as well as on female-headed

vs. male-headed households. To achieve these objectives, a parametric approach (endogenous switching regression model) is applied. The results indicate that the model detects selectivity bias. With the covariances between the error terms of the adoption equation and the expenditure equations for both adopters and non-adopters being negative, we conclude that they may have self-selected *into* and *out of* adoption. With the bias accounted for, adoption of cassava technology results in an approximately 10 percentage point reduction in the poverty rate. Given an adoption rate of 34 per cent and a 10 percentage point reduction in the poverty rate, an estimated 24,309 households (equivalent to 194,469 individuals) managed to move out of poverty as a result of adoption. This implies that cassava technology can be promoted as part of an effective poverty reduction and sustained agricultural growth strategy for Africa. Results disaggregated by type of household show that adoption of cassava technology has benefited female-headed households and the non-poor, relative to male-headed households and the poor. Targeted interventions will thus be more effective in terms of reducing costs, maximising average impacts and reducing poverty.

A comparison of the actual versus the potential impacts of adoption suggests that the non-adopters, had they adopted the technology, would have benefited more than what the actual adopters had, implying that continued dissemination efforts and reaching out to current non-adopters could increase the average impact of adoption on poverty reduction and is, therefore, worthy of investment. Currently, only 34 per cent of the cassava producers are adopters. Addressing the identified barriers to adoption (e.g. lack of access to extension, planting materials, credits and limited availability of resources) would allow exploiting the full potential of the cassava technology in poverty reduction. Considering the large realised and even more pronounced potential impacts of the adoption of cassava technology on poverty reduction, it is vital that regional and global development organisations working for the betterment of the African poor should continue to support the existing cassava improvement programme to sustain the technology development efforts in the continent.

Acknowledgements

The authors wish to thank the African Development Bank for supporting the multinational-CGIAR support to agricultural research for development of strategic crops (SARD-SC) in Africa project that made possible the collection of the data used in the study. We are also thankful to the International Institute of Tropical Agriculture for supporting this study. In addition, we would like to thank Paul Dontsop (IITA Bukavu, DR of Congo), John Ainembabazi (formerly IITA Uganda and currently AGRA, Nairobi, Kenya), Tesfamicheal Assfaw (IITA Abuja, Nigeria), Makaiko Khonje (IITA Lilongwe, Malawi) and Djana Mignouna (IITA Ibadan, Nigeria) for their contributions to the manuscript in terms of the establishment of the procedure applied to assess the impacts of adoption of the cassava technology on poverty reduction.

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Esther L. ACHANDI*[1] and Gaudiose MUJAWAMARIYA*[2]

Market participation by smallholder rice farmers in Tanzania: a double hurdle analysis

Smallholder farmers account for over 90 per cent of domestic rice production in Tanzania. Their participation in markets provides opportunities for growth through income and employment. However, their ability to participate is hampered by personal, household and institutional constraints. We adopt the double hurdle model to explore determinants of market participation by rice farmers using data collected from selected rice growing regions in Tanzania. The decision to participate in the market is affected by the cropped area, yield, distance to the market and type of variety grown. Besides these factors, the quantity marketed is affected by the existence of a market within the village. There is need for labour-saving technologies for area expansion and yield improvement.

Keywords: average partial effects, rice marketing, developing country

* Africa Rice Center, Tanzania Station, P.O. Box 33581, Dar es Salaam, Tanzania. Corresponding author: g.mujawamariya@cgiar.org

Introduction

Product marketing plays a key role in the process of agricultural development and in stimulating and extending development opportunities (Abbott, 1993). The increase in production of food crops requires effective demand from outside the farming area in the form of population growth or demographic change (von Braun *et al*., 1994). Such demand increases commodity prices. The importance of markets to smallholder farmers entails several facets: (a) households derive benefits such as income and open opportunities for rural employment (Dorward *et al*., 2003), and (b) marketing activities such as processing, transportation and selling provide avenues of employment for smallholder farmers willing to exit the farming sector (Jari and Fraser, 2009).

In spite of the market importance, a farmer's ability to take advantage of the existing market opportunities is highly dependent on personal and institutional factors. For instance, age can have a positive or negative effect on market participation: older farmers may be more concerned about food security while the young farmers may want to enhance the quality of their lives through participating in the market (Musah *et al*., 2014). Furthermore, households that have more dependants may be associated with higher levels of consumption, thus lowering their marketable surplus (Ehui *et al*., 2009). The gender of the household head can also affect market participation, with male headed households expected to participate more in the market (Reyes *et al*., 2012) while female headed households are less likely to participate in the market due to higher transaction costs of searching for buyers, contracting and enforcing of sales as compared to their male counterparts (Jagwe *et al*., 2010). Jaleta *et al*. (2009) find that household crop market participation is determined by the literacy level of the head of household and household's market orientation. Namazzi *et al*. (2015) further explain that literacy level of a farmer has a positive effect on the level of participation in the market as it determines how the farmer makes marketing decisions and interprets market signals. Makhura *et al*. (2001) and Gebremedhin and Jaleta (2010) find that distance to the market negatively influences both the decision to participate in the market and the proportion of output that is sold. Furthermore, Fafchamps and Hill (2005) show that wealthy farmers can sell their produce at distant markets given that they can afford high transport costs as compared to poorer farmers.

Despite the highlighted importance of marketing, key factors that can boost commercialisation of rice in the developing world are less well known, even in a situation where rice is recognised as a major cash crop.

The objective of this paper is to determine the key factors that affect smallholder farmers' decisions to market as well as those that affect quantities sold when they participate in the market. The study takes the case of the rice sector in Tanzania where there has been much emphasis on production but where pertinent marketing information is lacking. Rice is the second most important crop after maize and 90 per cent of all rice production is undertaken by smallholder farmers. Annual milled rice consumption is estimated at 25-30 kg per capita and the growth rate of rice consumption is estimated at an average of 4 to 7 per cent for the period 2007-2012 as a result of income growth, urbanisation and the perception of its ease of cooking and storage (MAFC, 2009; Stryker, 2013). Locally-produced rice has wider market potential as it is preferred to imported rice, especially due to its aromatic attributes.

Methodology

Marketing studies are plagued with the possibility of recording zero sales or purchases for certain commodities. These observed zeros are in some cases genuine corner solutions, for instance when some farmers decide not to participate in the market in an optimising behaviour. The outcome is continuous for other farmers in terms of the intensity of participation. Two distinct decisions are observed: a participation decision and a supply volume decision, also described as the extent of participation (which is measured in quantities). While some authors take these decisions as being simultaneous, implying that the same vector of parameters determines both decisions, other studies in the literature assume sequential decisions. In this case, the two decisions are determined by a different set of explanatory variables (Bellemare and Barrett, 2006).

The Tobit model (Tobin, 1958) is sufficient to accommodate the zero observed figures alongside other positive val-

[1] http://orcid.org/0000-0001-9705-3712
[2] http://orcid.org/0000-0003-0087-8529

ues if simultaneity of decisions is assumed. The participation decision hence becomes irrelevant and the observed zeros imply that the producer does not participate in market. This limitation undermines the sufficiency of the Tobit model for empirical analysis. Cragg (1971) proposed a two-tiered process, namely the double hurdle model, which incorporates relevance of the participation decision to the Tobit model with the probability of participation and the intensity of participation being determined by separate processes. The idea behind the double hurdle model is looking at an event that may or may not occur. Occurrence of the event is associated with a continuous positive random variable while if the event does not occur, the random variable takes a value of zero. Such is the decision about market participation. It is guided by a latent variable model linking unobserved utility derived from market participation to the behaviour observed.

The individual's decision to participate in rice marketing can be represented by:

$$d_i^* = Z_i'\alpha + u_i \quad (1)$$

where d_i^* is a latent variable indicating whether or not the individual participates in marketing, α is a vector of unobserved parameters to be estimated, Z_i is a vector of observed independent covariates that explain an individual's decision and u_i is an unobserved error term capturing all other factors.

The extent of participation is indicated by:

$$y_i^* = X_i'\beta + v_i \quad (2)$$

where y_i^* is the amount marketed, X_i is a vector of covariates that explain this amount, β is a vector of unobserved parameters to be estimated and v_i is a random variable indicating all other factors apart from X. An individual will participate in marketing if $u_i > -(Z_i'\alpha)$ with the probability of observing the individual participate in marketing given as $P(u_i > -(Z_i'\alpha))$. The model gives room for possible differences between factors that affect participation $(u_i, Z_i'\alpha)$ and factors that affect extent of participation $(v_i, X_i'\beta)$.

The interaction between the two decisions leads to the following estimation for the model:

$$\left.\begin{array}{l} y_i = X_i'\beta + v_i \ \ if \ \ y_i^* > 0 \ \ and \ \ d_i^* > 0 \\ y_i = 0 \ \ otherwise \end{array}\right\} \quad (3)$$

While the double hurdle model provides us with an understanding of which factors affect each stage in the decision making process, Yen and Jones (1996) highlight its key limitation, namely that it decomposes the effects of the first hurdle onto the second hurdle while interpreting the results. Consequently, to understand the overall effect of explanatory variables in the first and second hurdles, we follow Burke's (2009) approach by incorporating the likelihood function and the partial effects of both hurdles in the calculation of the average partial effects (APE) of these variables and using bootstrapped standard errors.

For the variables that explain participation in the market and extent of participation, data were collected from seven major rice growing agroecological zones of Tanzania. Twenty one districts were proportionately sampled based on the 2002/03 and 2004/05 rice production data. About five villages were randomly selected from each district, and ten rice growing households were selected from each village giving a target sample size of 1040 smallholder farmers. After dropouts and missing data considerations and aggregation at the household level, the effective sample was 676 households.

Results

The results do not reveal any influence of personal characteristics on the decision to participate in the market or quantity of rice that is sold. Cropped area and yield positively affect the decision of the household to market rice, while growing an improved variety and distance to the market negatively affect decision to participate in the mar-

Table 1: Descriptive statistics of the non-marketing and marketing rice growing households surveyed in the study and maximum likelihood estimates of double hurdle model for market participation (total n=676).

Variable	Non-marketing (n=115)	Marketing (n=561)	ANOVA/ Chi-square	First hurdle (participation)	Second hurdle (quantity)
Paddy sold (tonne)	0	2.09 (2.07)	***		
Share of sold rice over production (%)	0	0.67 (0.26)	***		
Age (years)	43.7 (12.0)	44.5 (13.0)	NS	-0.04 (0.03)	0.10 (0.09)
Age squared				0. 00 (0.00)	-0.00 (0.00)
Gender of household head, HH (1=male)	0.83 (0.38)	0.81 (0.40)	NS	-0.24 (0.20)	-0.23 (0.56)
Marital status of HH (1=married)	0.81 (0.40)	0.82 (0.39)	NS	0.18 (0.20)	-0.59 (0.59)
Education (1=above primary)	0.17 (0.37)	0.12 (0.33)	NS	-0.19 (0.17)	0.64 (0.50)
Ecology (1=irrigated)	0.30 (0.46)	0.32 (0.47)	NS	0.15 (0.13)	-0.29 (0.39)
Cropped area (ha)	2.21 (2.23)	2.65 (2.23)	*	0.06 (0.03)**	0.94 (0.08)***
Variety grown (1=improved†)	0.29 (0.45)	0.22 (0.41)	NS	-0.28 (0.14)*	0.98 (0.42)**
Yield (tonne/ha)	1.17 (1.42)	1.41 (1.28)	*	0.11 (0.05)**	1.40 (0.13)***
Existence of market within the village (1=market exists)	0.28 (0.45)	0.29 (0.46)	NS	-0.06 (0.14)	0.97 (0.43)**
Distance to nearest market (km)	6.97 (12.57)	5.21 (6.81)	**	-0.01 (0.01)*	0.06 (0.03)**

ANOVA test is performed for continuous variables and Chi-square test is performed for categorical variables
*/**/*** statistically significant at the 10%, 5% and 1% levels respectively
NS: not significant
† Varieties classified as improved are TXD 306 (commonly known as SARO5), TXD 85, TXD 88, IR54, IR56, IR64, Improved ADRAO Nerica and Improved ADRAO non-Nerica while other 105 varieties were classified as non-improved.
Source: own calculations

ket. The quantity of rice sold is positively influenced by the cropped area, variety type, yield, existence of a market and distance to the market (Table 1).

The unconditional APE for continuous variables that were significant in affecting quantity of milled rice sold are shown in Table 2. For each additional hectare of cropped area, the sale of rice increases by 0.32 tonnes on average. The variable yield bears the expected sign with an increase of 1 tonne per hectare leading to an increase in the quantity of milled rice sold by 0.47 tonnes on average. Following this process however, distance is now found to be not statistically significant in affecting quantity of rice sold.

For the nominal and ordinal variables that affect quantity of rice sold, we compare the average values of milled rice by category in Table 3. Married household heads sell more rice than the non-married household heads. Male-headed households sell on average more rice than the female-headed households. The less-educated household heads sell more rice than the more-educated household heads. Smallholder farmers who grow rice on irrigated land also sell more on average than those who grow rice in rainfed lowland areas. When a market exists within the village, farmers sell more rice than when markets do not exist. The average rice marketed varies significantly only across the category of variety type with those growing improved varieties selling more rice.

Table 2: Unconditional average partial effects (APE) for factors affecting quantity of milled rice sold.

Variable	APE (bootstrapped S.E.)
Cropped area	0.32*** (0 .04)
Distance to market	0.01 (0.01)
Yield	0.47***(0.08)

*/**/*** statistically significant at the 10%, 5% and 1% levels respectively
NS: not significant
Source: own calculations

Table 3: Average rice sold in tonnes for nominal and ordinal variables.

Variable	Category	Average rice sold (S.D.)	ANOVA
Gender of HH	Male	1.75 (2.05)	NS
	Female	1.64 (2.02)	
Marital status	Married	1.77 (2.07)	NS
	Not married	1.58 (1.88)	
Education level	Primary	1.73 (2.05)	NS
	Above primary	1.71 (1.99)	
Ecology type	Irrigated	1.75 (2.14)	NS
	Rainfed lowland	1.72 (1.99)	
Variety grown	Traditional	1.64 (1.88)	**
	Improved	2.05 (2.48)	
Existence of market within the village	No market	1.69 (1.94)	NS
	Market	1.84 (2.26)	

** statistically significant at the 5% level
NS: not significant
Source: own calculations

Discussion

Our findings on the effect of land ownership on market participation corroborate those of Ohen *et al*. (2014) who found that households with more land have the capacity to cultivate more of the crop and expand their production to ensure adequate supply to the market. Farmers owning small farms may not be able to raise the necessary surplus to sell at the market. Furthermore, higher yields boost the farmer's likelihood to participate in the market because of the surplus above their household consumption needs. The novelty of our findings is that, contrary to popular belief that growing improved varieties can catalyse farmers to produce intentionally for the market, the reverse has been seen to be true. Indeed, growing improved rice varieties makes the farmer less likely to participate in the market, probably due to consumer preference for traditional aromatic varieties. Consumer preferences for specific rice types and qualities are often entrenched (Calpe, 2006), which limits the scope for substitution between different varieties.

When markets are perceived to be far, the farmer's decision to produce for the market is negatively affected. This is associated with the high transaction costs of selling in distant markets. Makhura *et al*. (2001) and Siziba *et al*. (2011) also found distance to market to have a negative and significant effect on both the farmer's decision to participate and the extent of farmer participation in the market. We would also expect a negative relationship between distance and the quantity sold, but our result shows the contrary. It may be that rice is sold in markets further away from the villages when the unit transport cost to travel is low, especially for wealthy farmers (Fafchamps and Hill, 2005). Moreover, farmers may not travel to the market if rice is bought from the villages by traders and millers. Indeed, Kilima (2006) indicates that much of the trade in rice is conducted by traders and not farmers. While moving from growing traditional to improved variety has a negative effect on the decision to participate in the market, once the first hurdle is crossed, this has a positive effect on the quantity sold to the market due to the higher yields attained from the improved varieties which translate into marketable surpluses for farmers. The higher yields imply the possibility to grow marketable crops (Smale *et al*., 1995).

The finding that cropped area and yield affect both the decision to market and the quantities that smallholder farmers actually sell is important as it supports the need for agronomic efforts to improve market-oriented rice production. Labour-saving technologies, such as tractors and power tillers, that can help farmers expand their cropped area are required. However, land expansion is not always achievable, especially where there are other demands on land such as expanding urban area and production of other crops. Rather, the yield enhancing practices can be more promoted, such as rice varieties that meet consumer preferences, and good agricultural practices, including the use of fertilisers and other inputs, that can help in increasing yield and thus enhancing market participation.

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JUHÁSZ Anikó

BioEast: Central Eastern European Initiative for Knowledge-based Agriculture, Aquaculture and Forestry in the Bioeconomy

Introduction

Over the last ten years the resources of the Common Agricultural Policy have helped the Central and Eastern European (CEE) regions of the European Union (EU) to improve their agri-food sectors, environment and rural areas, thus increasing economic and social cohesion. However, in order to achieve further progress in the sustainable growth of agriculture, aquaculture and forestry in the bioeconomy, much more emphasis on research, innovation and transnational cooperation for knowledge-based development is needed. BioEast is a new strategic research agenda for achieving this greater emphasis that is to be submitted to the European Commission (EC). The EC has indicated that it would welcome such an initiative as it recognises that the imbalances in research, innovation, cooperation and lobbying between the regions are hindering the sustainable growth in the whole EU.

The proposed actions under the BioEast initiative are as follows:

- *Initiate cooperation*: establish a multi-stakeholder network to facilitate joint actions;
- *Provide an evidence base*: establish data-driven support for implementation of policies;
- *Focus on research*: map specific challenges for a Strategic Research Agenda;
- *Improve skills*: train a new generation of dedicated multi-stakeholder actors;
- *Develop synergies*: promote regional, national, EU and international funding opportunities;
- *Increase visibility*: draw attention to specific challenges of the CEE regions of the EU.

In summary, the aim of BioEast is to address agricultural, bioeconomy and rural policy and governance challenges in the less developed EU regions that form part of the Continental and Pannonian bio-geographical regions of Europe.

The Continental and Pannonian Bio-geographical Regions

A biogeographical region can be defined as an area of animal and plant distribution having similar or shared characteristics throughout. The EU has nine terrestrial biogeographical regions (Alpine, Atlantic, Black Sea, Boreal, Continental, Mediterranean, Macaronesia, Pannonian and Steppic). Most of the territory of the CEE regions of the EU belongs to the Continental and Pannonian Bio-geographical Regions. As is already the case for the Mediterranean Bio-geographical Region, Region-specific research topics and coordination and support actions are needed which reflect the climate specificities. Specific and extreme changes in the weather resulting from the very nature of these Regions can be expected in the near future, and adaptation in agriculture and the bioconomy is a challenge. Key areas include crop production, animal husbandry, forestry, aquaculture and food processing, and topics such as cooling and heating, pest and disease control, risk management, and knowledge transfer. The identification and implementation of specific research areas would not compromise the principle of excellence in research, on the contrary it would enhance it. Similarly, it would not mean the exclusion of other Regions from the research: the experiences of other Regions (e.g. Mediterranean drought and Atlantic storms) would be essential for reaching relevant results.

However, in many of these CEE regions the current levels of research, innovation, cooperation and lobbying are substantially below the EU average, and this research and innovation divide in Europe hinders both the unlocking of excellence in these regions and the appearance of specific research topics relevant to the Continental and Pannonian Bio-geographical Regions in the EU's Horizon 2020 work programmes. In turn, the low performance and topic representation block the realisation of the European Research Area and the promotion of synergies with the European Agricultural Fund for Rural Development (EAFRD), the European Maritime and Fisheries Fund (EMFF) and the European Structural and Investment Funds (ESIF).

Policy and governance challenges in the less developed EU regions

The economically less developed regions of the EU, which predominantly belong to CEE Member States, have several social challenges in common, all of which directly affect the development of their agriculture, bioeconomy and rural areas. Once again, the research and innovation divide in Europe hinders the appearance of research topics in Horizon 2020 work programmes that address specific needs of these regions. Research is needed on how to overcome such common economic and social challenges as the low uptake of innovation and modern technologies, the low level of cooperation, the consequences of the ageing population, the difference between the employment rate in predominantly rural regions and predominantly urban regions, and the extremely low level of consumer awareness. Once again, targeted topics would not mean the exclusion of other regions from the research; in fact, the experiences of the more developed regions would be essential for reaching relevant results.

The thematic scope of BioEast

BioEast has two themes and, within these, 13 topics. Topics 1-7 are part of Theme 1, *Climate change challenges in the Continental and Pannonian Bio-geographical Regions*,

and topics 8-13 fall under Theme 2, *Policy and governance challenges in the economically less developed EU regions*. The specific challenge, potential output, scope and expected impacts envisaged for each topic are as follows:

Topic 1: *Sustainable intensification by maintaining soil conditions and improving water management.* The intensity of agricultural production in the CEE regions has been lagging behind that of the other parts of the EU for many years. For example, farms are smaller, fertiliser application rates are lower and cereal yields are also lower. Targeted research is needed on how the intensity of agricultural production could be increased through sustainable land use, soil conservation and cost- and environment-sparing methods i.e. by ensuring adequate water and nutrient management taking into account the possibilities offered by the bioeconomy and the circular economy. A monitoring system is required that evaluates the economic and environmental performance of various tillage systems and precision agriculture under various climatic and soil conditions (e.g. drought) and under different cropping patterns. This system would analyse and monitor the impact of conservation tillage and precision agriculture systems on soil water storage capacity, precipitation storage efficiency, soil degradation processes, yields and input costs. The analyses and databases would support farmers in making decisions about the application of new agro-technology that facilitates the adaptation to climate change, to avoid soil degradation and economic difficulties.

Topic 2: *Sustainable extensification by maintaining biodiversity and ecosystem services.* While there is an increase in the demand for genetically homogeneous crop and animal species, the genetic diversity of cultivated species has been dramatically reduced. There is a need for the maintenance and enhancement of biodiversity of cultivated plants, domesticated animals and cultures of microorganisms, strengthening of natural self-regulating processes, protection and maintenance of the biological status of soil, and a reduction in unfavourable environmental impacts arising from inadequate nutrition management. These are essential measures to protect the environment, the farmers and the health of consumers. Research would show how to ensure most efficiently the preservation of biodiversity and the production of sufficient food through combining extensive production and green infrastructure elements (integrated land use, green corridors, creating habitat patches etc.). Green infrastructure is a concept linked to several EU policies and a tool to tackle biodiversity loss while contributing to smart and sustainable socio-economic growth. It provides us with solutions for a better quality environment, a healthier society and a more prosperous economy. This work would promote the movement of species between Natura 2000 areas; establishment of connections between natural sites through green corridors; mitigation of habitat fragmentation; increasing the ecological value of landscapes; and multifunctional agricultural land use.

Topic 3: *Improvement of organic farming in terms of production technology.* In many CEE regions, technologies, decisions and support that hinder the development of the organic sector are not consistently recognised. The implementation of effective organic production requires awareness-raising and the reduction of post-harvest crop (food) losses. Research is needed on how to improve the unbalanced production structure, the low rate of use of organic seeds and manure, the small extent of processing and the low levels of market organisation and coordination. Eco-functional (organic or integrated) production systems should be designed and applied that provide, in addition to optimal resource utilisation and low environmental (load) effects, high and reliable quality food products. New production systems (agro-ecological provisioning plants, intercropping, ground cover plants) that exploit plant diversity and variability to meet agronomic and environmental (agro-ecosystem) demands should also be developed. Such integrated agro-ecological systems and organic production contribute to the maintenance of the nutrient cycle, to the increase of soil productivity, to weed suppression and to the maintenance of indigenous insect species. This work will enhance the functioning and efficiency of market organisations, increasing market coordination, and promote the development and implementation of ecologically important organic production systems and technologies and achievement of efficient resource use and minimised amounts of waste.

Topic 4: *The reduction of high dependence on non-renewable energy sources.* Agriculture in CEE regions tends to be highly dependent on fossil fuels, and it should improve its energy efficiency by using its energy production capabilities to cover its own energy needs as much as possible, thereby contributing to increasing energy security and improving competitiveness. Long-term viability of on-farm green energy production in many cases depends on the level of farm energy consumption. In order to judge investments and to monitor the impact of Common Agricultural Policy (CAP) measures, it is necessary to get to know the typical electricity use of different farm types and the amount needed to produce one unit of product. Presently available CAP indicators are based on estimations, or macro-level models. Additionally, no background analyses and no research documents have been published to support CAP legislation concerning this area. As research outputs, baseline estimations will be given for the electricity consumption of the major sectors of agriculture and the strongly integrated processing activities. Daily, monthly and the seasonal distribution of consumption will be supplied. Methodological problems of measuring specific consumption will be identified and recommendations will be made for their resolution. The long term viability of an on-farm energy production concept will be evaluated.

Topic 5: *Exploiting the potential for protein crop production.* Protein crops have a marginal position in EU cropping systems and the EU is dependent on imported protein. CEE regions have the necessary conditions to produce more protein crops but there is a lack of suitable varieties, profitability and nutrient contents are low, market mechanisms are underdeveloped, there are barriers to uptake in livestock feed and no non-GMO premium. Knowledge sharing systems that help farms to increase their production efficiency are also missing. After the examination of soil and climatic conditions, the research will provide a portfolio of improved protein crop varieties suited to specific agro-ecosystems along with region-specific farming practices and the results of the nutritional analysis of protein crops. A representative set of farms will provide data

regarding their entire protein crop production practices. From these data, recommendations for specific production practices will be prepared for each production region and published in a form of a guide. A consultancy network will be established and operated on the basis of the results. The network, which covers recommendations on production practices adapted to the place of production and data of representative farms, will facilitate, in parallel with the improvement of profitability, the wider spread of protein crop production.

Topic 6: *Strengthen the Regions as buffer zones against emerging and evolving pathogens.* There is insufficient understanding of the synergetic effects of climate change, European integration and globalisation. Trade liberalisation facilitates the trade of living and processed animal and plant products (and their packaging materials). Economically beneficial trade liberalisation increases our vulnerability from the animal health and phytosanitary point of view (e.g. African swine fever, bovine besnoitiosis). Moreover, the impact of climate change increases the possibility of modified disease behaviour, making disease spread easier and causing a European level problem (e.g. grape and apricot phytoplasma). Our understanding of the synergetic effects of these two trends (increased trade and climate change) on animal and plant health will be enhanced with the help of a 'buffer zone scientific network' to support monitoring and stopping these transboundary pathogens in the CEE regions, and where possible saving the rest of Europe from the economic losses.

Topic 7: *Sustainable, efficient and competitive freshwater fish production.* Freshwater aquaculture represents 21 per cent of all EU aquaculture production and is located mainly in the Continental and Pannonian Bio-geographical Regions. Limited resources such as water scarcity and the demands of ecosystem services represent increasing challenges to the competitiveness of fish farmers, as do the consequences of the changing climate. Research is needed on how to improve the economic viability of freshwater fisheries while increasing environmental sustainability, in order to unlock the potential in freshwater aquaculture of promoting the rural economy and providing ecosystem services. This will involve building detailed, standardised databases and analysing production performance by evaluating potential fish production and efficiency under various pond conditions, taking into account the expected effects of different climate scenarios and sustainability. These databases on aquaculture will enable long-term, comprehensive analysis of production data and factors of climate change. Based on the results, guidance can be offered on how to reallocate input resources and improve technical efficiency, and how to adapt to changing climatic conditions. This will support farmers in making decisions on implementing improved management practices to adapt to climate change and market conditions in a sustainable manner. It will also help the creation of multi-functional systems (including angling and tourism).

Topic 8: *Motivating knowledge-based modern farming and cooperation among farmers.* Family, small and young farmers in less developed EU regions generate much lower levels of agricultural production value than do their western European counterparts. The reasons include the limited flow of information, and lack of knowledge and cooperation. Research is needed on how to involve young farmers in the adaptation of good practices, boost innovation and cooperation, create possibilities for expanding farming and support knowledge sharing. The same shall apply to both data usage and adequate machine service. The deepening of cooperation is crucial and the understanding and overcoming of trust barriers is important. A pool of scientific and practical resources will be collected and analysed regarding the processes of knowledge sharing among farmers in the less developed EU regions. As an output, a detailed list of problems and potential solutions will be identified in consultation with the relevant stakeholders. This work will give important input to improving the agricultural knowledge and innovation system in the less developed regions, especially in CEE countries, and encourage the development of knowledge-based, modern farming and the more effective cooperation between relevant stakeholders from the research, government, business and civil spheres, the so-called 'quadruple helix'.

Topic 9: *Supporting the generation change of the first entrepreneurs in the agri-food sector*. In many CEE regions, agricultural workplaces are unattractive due to the physical work, low wages and seasonality, and the age structure of the farm managers is characterised by the high and increasing share of the older generation Succession is made extremely difficult by the fact that there are no family or social patterns to follow as this is the first significant generation change since the regime change. If the issues of generational renewal in an enterprise and the labour reinforcement are solved, the probability of longer-term profitable and large-scale investments increases. Therefore, effective generational change in the agri-food enterprises has a key role in the future of the whole sector. It is necessary to map adaptable, innovative and complex government interventions promoting generational change, and systematise and disseminate good practices in which exemplary generational change has been carried out. Examples include the cooperation of young, start-up enterprises in the agri-food sector, projects implemented under the European Innovation Partnership 'Agricultural Productivity and Sustainability', and their participation in networks. Through the long term generational renewal in agriculture and the food industry, the number of farms operated by young entrepreneurs open to innovative solutions and the sustainable use of natural resources can increase.

Topic 10: *Improving supply chain efficiency and increasing its added value.* Supply chains in the less developed EU regions have lower efficiency and added value. How can the effectiveness of these supply chains be improved? Where and how can the value added be increased? Which special consumer needs have to be met? Why are these regions lagging behind in terms of innovation financed by own resources? What are the brand potentials? How can vertical cooperation be strengthened? Can by-products and waste materials produced at any stage contribute to the supply chain sustainability and competitiveness? Research is needed on the following areas: better satisfying the consumers' needs, increasing value-adding through innovation, trademarks, enforcing the connections within the value chain both vertically and horizontally, and increasing the effectiveness of the value chain by reducing waste and other unnecessary costs. With special regard to the most difficult value chains with many stakeholders, the research will identify the barriers to the effective

operation of supply chains, and will pay special attention to the cooperation, integration and the buyer power within the value chain. As a result, the value chain will be more effective, the products will be more marketable and the food waste and environmental pollution will be reduced.

Topic 11: *Increasing consumer awareness despite a significant lack of confidence and price sensitivity*. Consumers in the less developed CEE regions have low willingness to remunerate environmental services etc. provisioned by agriculture when they have different preferences and lower purchasing power than consumers in more developed EU regions. Most households are very price sensitive, and research is needed on how to improve nourishment in these circumstances. Individuals need to have access to sufficient and good quality food and they need an understanding of what constitutes a good diet for health, as well as the skills and motivation to make good food choices. It is necessary to investigate how big a price premium CEE consumers will pay for healthy food, to analyse how the production side can produce healthy food with a smaller price premium which is acceptable to CEE consumers, and to explore the knowledge level of the consumers about healthy products and the most important barriers to consumption of healthy food. An investigation of the main reasons for the lack of confidence and a set of recommendations on how to increase consumer awareness, unified information and a promotion programme for consumers are needed. Based on this information, recommendations can be made in order to increase the knowledge and awareness of the consumers.

Topic 12: *Increasing the value added use of agricultural and forestry biomass*. There are several critical points to improving the use of agricultural and forestry biomass in less developed EU regions. Economic viability often conflicts with ethical and sustainability aspects. Research is needed on how to unlock the great and mostly unutilised potential for biomass production and added value utilisation in the less developed EU regions while respecting the sustainability requirements and increasing the economic benefits in the production regions. Since biobased industries and especially non-traditional higher value added biomass utilisation will depend on financial support at least in the mid-term, policies must find solutions for the conflicting aspects. Some sort of hierarchy of use must be developed for particular biomass forms, and for various conversion platforms adaptable to different conditions. From this work, guidelines will be developed for biomass utilisation, and different platforms will be evaluated from various aspects.

Topic 13: *Experiences of less developed EU regions in social integration challenges such as food, energy and social care security*. Internal migration from rural to urban areas of the EU has resulted in a concentration of undercapitalised population in peripheral rural areas, and now international migration to the EU is accelerating. Owing to these migration processes, the EU, and especially its developed regions, face several challenges, such as population growth, changing consumer habits, and rising global demand for food and public goods. Comprehensive examination of challenges originating from the intensification of international migration will enable the most sensitive issues from the point of view of food, energy and social security to be identified, both at the EU and regional levels. It is necessary to collect good local and regional policy and governance practices and develop underlying strategies and action plans to manage new security needs efficiently and enable the sustainable development of food, energy and social care provision capacities and skills to exploit the supply and employment potential at a higher level. A comprehensive analysis will contribute in the long term to the satisfying production of the EU's agricultural, bioeconomy and rural stakeholders according to the changes in the number and composition of the population, making it easier to increase their income generating ability and their standard of living.

Implementation of the BioEast strategic research agenda

In the last year and a half, the lead organisers of BioEast have been doing fact-finding and organisational work with the active involvement of stakeholders, and have become increasingly actively involved the policy work at EU level through bodies such as the Standing Committee on Agricultural Research Strategic Working Group on Agricultural Knowledge and Innovation Systems and the Programme Committee for implementing Horizon 2020 Societal Challenge 2 *Food security, sustainable agriculture and forestry, marine and maritime and inland water research and the bioeconomy*.

Several successful events have been organised, during which topics and challenges specific to the region were identified by agricultural stakeholders, for example the workshop 'Policy Guidelines for Agricultural Research' (see *Studies in Agricultural Economics* volume 117 number 3) and the workshop and conference described in this issue. The topics listed above have been identified as a result of these activities. They are in line with the targets of Hungary's National Smart Specialisation Strategy (S3 Strategy), contribute to the long-term agricultural and innovation strategy of the EU's Directorate-General for Agriculture and Rural Development (*Towards a long-term strategy for European agricultural research and innovation by 2020 and beyond*) and are connected with the bioeconomy strategy. The topics are currently undergoing regional validation, a process which demands close professional and political cooperation among countries of the region. In the case of the topic *Strengthen the Regions as buffer zones against emerging and evolving pathogens* a regional cooperation agreement has already been signed by a large number of participating actors.

For further information about BioEast, see http://eip.fm.gov.hu/?page=pages&page_name=bioeast-kezdemenyezes. To turn BioEast from a strategy into reality, what is now needed is to develop further such examples of cooperative action. In order to achieve synergies and significantly improve the performance of the CEE regions in agriculture, aquaculture, forestry and bioeconomy, these should encompass different groups of stakeholders (such as farmers, researchers and policy makers). *If you and/your organisation is interested in supporting BioEast, please contact Juhász Anikó PhD, General Director of AKI, at juhasz.aniko@aki.gov.hu.*

Workshop and conference report

FM-NAK-AKI Agricultural Research Strategy and EIP-Agri Conference

Budapest, 14 January 2016

This workshop and conference was organised jointly by the Hungarian Ministry of Agriculture (FM) and the Hungarian Chamber of Agriculture (NAK) with the assistance of the Research Institute of Agricultural Economics, Budapest (AKI). The aim of the event was to provide information to Hungarian farmers on innovation and cooperation based on tender opportunities in agriculture. The conference helped farmers to identify specific problem areas and research topics of relevance by offering them the opportunity to express their opinion on the main strategic areas of research outlined by the national agricultural research workshop held on 10 November 2015 (see *Studies in Agricultural Economics* volume 117 number 3). The event was well attended: 84 persons participated in the workshops and 252 in the public conference.

In the first presentation of the plenary session, Kránitz Lívia from FM explained how Hungary has formulated its agricultural research and innovation policy guidelines. Then Juhász Anikó, General Director of AKI, identified the areas of Horizon 2020, the European Union's research and innovation programme, that are of particular relevance to applicants from central and eastern European countries. The plenary session ended with the presentation of Kovács Barna, from the European Commission's DG Research and Innovation. He pointed out that financial support to agricultural research is increasingly becoming a priority for the EC. Research funding available during the 2014-2020 programming period is double that of the previous period.

As an introduction to the workshop, the moderators introduced the most important problems, research questions and directions, and project ideas, and the participants were asked to complete them. In the second round, topics that are of importance to producers and that could be addressed through actions under the new EU European Innovation Partnership 'Agricultural Productivity and Sustainability' (EIP-Agri) were gathered. For the 3-4 most significant topics, sources of research support were identified as technical assistance to implement specific ideas. In addition, farmers were invited to commit themselves to participate actively in a research project. Furthermore they were asked to define the possible users and the beneficiaries of potential research results. As a conclusion, the participants stated whether they were or are currently in contact with research centres and, if so, with which ones.

The topics discussed were:

- Managing challenges caused by the continental climate and its change:
  - The reduction of dependence on non-renewable energy sources;
  - Exploiting the potential for protein crop production and livestock feeding;
  - Central and eastern Europe as an east-west/south-north buffer zone for pathogens;
  - Preservation of the quality of natural resources, ecosystem services and biodiversity.
- Adaptation to the challenges of social and economic changes:
  - Opportunities for promotion of modern management in agriculture;
  - Efficiency of the supply chain, increasing the added value, bio-economy;
  - Alternative effects on consumer attitudes.

The farmers played an active role in all of the groups. They supported most of the focus areas identified by researchers. They extended these areas in every case and contributed to the discussion with practical and helpful examples. Altogether the attendees produced 60 project ideas that offer solutions for the problems identified. In addition, almost all group members showed high interest in joining the proposed research projects. Actually, many of the farmers have already had some links with research institutes, almost all of the institutes received positive feedback in this regard according to the questionnaires. The interest of the attendees in the event serves as an indicator of the openness of the market players for research, development, innovation and collaboration. But it is important to mention that this positive attitude does not yet exist in the whole agricultural sector. Therefore, one of the most important tasks is to encourage farmers currently without an open mind towards such projects to participate. NAK will play a key role in this task.

In the first presentation of the afternoon session of the conference, Mezei Dávid, the Deputy Minister of State for Agriculture, Rural Development and Strategic Affairs at FM, reviewed the possibilities for innovation projects in the field of agriculture, food processing and forestry. Feldman Zsolt, Deputy Secretary of State for Agriculture at FM, then described the development of the agri-innovation network in Hungary. FM is responsible, with the support of NAK, for setting up the Hungarian network of the EIP-Agri, the aim of which is to stimulate progress in the sectors and provide bases for long-term development. Papp Gergely, the Technical Deputy Director General of NAK, talked about the contribution of his organisation in setting up the network. Then, Vásáry Viktória from AKI introduced the new Hungarian EIP-Agri website which has been developed by AKI, with assistance from NAK, on behalf of FM. This website is a Hungarian-language portal for EIP-Agri that provides dynamic content management and entitlement-based access, based on the example of the EU's own EIP-Agri website (http://ec.europa.eu/eip/agriculture/).

Finally, two best practices were presented, one on developing environmentally-friendly plant protection technologies in fruit production systems, and the other on organic farming.

More information about the planned agri-innovation network is available by email from Dr. Juhász Anikó at juhasz.aniko@aki.gov.hu.

Studies in Agricultural Economics

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