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Roles of Agricultural Transformation in Achieving Sustainable Development Goals on Poverty, Hunger, Productivity, and Inequality*

Katsushi S. IMAI

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Research Institute for Economics and Business Administration

Kobe University

2-1 Rokkodai, Nada, Kobe 657-8501 JAPAN

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Katsushi S. Imai
Department of Economics, The University of Manchester, UK, & RIEB, Kobe University, Japan

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Abstract

This paper examines the role of the transformation of the rural agricultural sector in achieving Sustainable Development Goals 1, 2 and 10 drawing upon the cross-country panel data over the past four decades for 105 developing countries. We define agricultural transformation by three different indices, namely, (i) the agricultural openness index – the share of agricultural export in agricultural value added of the country, (ii) the commercialization index - the share of processed agricultural products, fruits, green vegetables, and meats in all primary and processed agricultural products, and (iii) the product diversification index to capture the extent to which the country diversify the agricultural production. Drawing upon the dynamic panel model, we have found that transformation of the agricultural sector in terms of agricultural openness has increased the overall agricultural productivity and its growth and has consequently reduced national, rural and urban poverty significantly. Agricultural openness alleviates child malnutrition, namely underweight and stunting, and improves food security in terms of energy supply adequacy, protein supply, lack of food deficit and reduction of the prevalence of anaemia among pregnant women. The agricultural openness is negatively associated with the Gini coefficient at both national and subnational levels for both rural and urban areas. Except for Latin America, product diversification reduces agricultural productivity, implying the efficiency gains from economies of scale of fewer crops. On the other hand, the commercialisation does not generally increase the agricultural productivity and this may be related to a positive effect of the higher share of cereal production on productivity observed in Sub-Saharan Africa and Latin America. Policies improving the efficiency of agricultural production, for example through better rural infrastructure, or promoting agricultural exports, through regional economic integrations or reducing transaction costs such as tariff and non-tariff barriers, would help to achieve SDGs indirectly through the productivity improvement.

JEL Codes: C23, I30, I14, O18, Q19
Key Words: Agricultural Transformation, Rural Transformation, Poverty, Inequality, Nutrition, Hunger, Sustainable Development Goals (SDGs),

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Corresponding Author: Katsushi S. Imai (Dr.): Department of Economics, University of Manchester, Arthur Lewis Building, Oxford Road, Manchester M13 9PL, UK; Email: Katsushi.Imai@manchester.ac.uk

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I. Introduction

While many of the middle and low-income countries across the world are still dependent on the agricultural sector in raising income and producing employment, the nature of agriculture has dramatically changed over the last four or five decades. In particular, the agricultural sector has experienced structural transformation, which has been induced by globalisation, industrialisation, and urbanisation. Despite economic growth, a large section of people in rural areas still suffers from abject poverty and malnutrition, implying that overall economic growth has bypassed many.

The growth-inequality relationship is intricately associated with the relationship between structural transformation and inequality. If labour productivity in rural areas rises at a slower rate than in urban areas, the disparity between rural and urban areas will widen. Rural-to-urban migration, however, could have an offsetting effect if migration is temporary and benefits more rural households than before during the urbanisation process. While many of the rural regions have benefited from more integrated wholesale and retailing networks and supply chains (e.g. expansion of supermarket chains to rural areas, horticulture or contract farming with multinational firms, agricultural production and sales more integrated with urban regions and developed world, and diversification of rural non-farm sector), whether it decreases inequality or not is unclear and depends on geographical distributions of these networks. If structural transformation increases overall productivity and outputs in rural areas, the structural transformation could reduce income inequality at national levels. However, if backward regions (e.g. mountainous areas) are left out of the structural transformation, it is likely to increase inequality. It is thus important to understand better whether inequality has increased as the country experienced structural transformation in rural areas.

Of particular importance in this context are farm and non-farm linkages and whether higher rural incomes are in part due to more diversified livelihoods and the emergence of high-value chains and the extent to which these have reduced rural-urban disparities and dampened migration. Apart from easier access to credit in order to strengthen farm/non-farm linkages, and smallholder participation in high-value chains, other major policy concerns relate to whether remittances could be allocated to more productive uses in rural areas,[1] through higher risk-weighted returns-specifically, and whether returns could be enhanced in agriculture and rural non-farm activities while risks are reduced (Imai, Malaeb, and Bresciani, 2016).

While a large body of the literature has confirmed that agricultural growth or development leads to poverty reduction (e.g. Christiaensen et al., 2011; Thirtle et al. 2003; de Janvry and Sadoulet, 2009), to our knowledge, there have been no work that has quantitatively analysed the effects of agricultural transformation - or the structural transformation of the agricultural sector - on poverty. A main objective of this study is to fill this gap in the literature and examine in detail the role of transformation of rural agricultural sector in achieving Sustainable Development Goal (SDG) 1 (poverty eradication), 2 (reduction of hunger and malnutrition and doubling agricultural productivity) and 10 (reduction of inequality) drawing upon the cross-country panel data over the past four decades for 105 developing countries. Methodologically, using the dynamic panel model, we will take account of the dynamic transmission of agricultural transformation to agricultural productivity – defined as log agricultural value added per worker and its growth as a broad measure of agricultural productivity as well as agricultural TFP growth (Fuglie, 2012, 2015). In this model, the agricultural transformation is treated as an endogenous variable by using the dynamic panel model to derive a useful insight into the causal relationships among key variables. Finally, we will apply the FE-IV model to take account of the effects of agricultural transformation on SDGs 1, 2 and 10 via improvement in agricultural productivity.

The rest of this chapter is organised as follows. After reviewing the concepts of agricultural transformation in Section II, we will provide three different measures of agricultural transformation we will use in this study in Section III. Section III also discusses our proxies for SDGs and summarises the data. Section IV then outlines empirical models to capture the effects of agricultural transformation on SDGs 1, 2 and 10. Section V reports and discusses the results of the models specified in Section IV. The final section provides concluding observations with policy implications.

II. Concepts of rural or agricultural transformation

While 'rural transformation' (*RT*) is a broader concept than 'agricultural transformation' (*AT*) as the former includes the transformation of non-agricultural sector, we will primarily focus on the structural transformation of the agricultural sector (*AT*). Conceptually, we draw and build upon Dawe (2015). While Dawe discusses in detail transformation of the agricultural sector of middle-income Asian countries, he does not provide a clear definition of 'agricultural transformation'. Citing Reardon and Timmer (2014), Dawe first discusses 'the structural transformation of economies' and then argues that *AT* is one of the five key transitions as a result of sustained income, that is, (i) urbanization, (ii) growth of the rural non-farm economy, (iii) dietary diversification, (iv) a revolution in supply chains and retailing; and (v) transformation of the agricultural sector. Consistent with the last transition, he argues that '(t)here are at least three key changes that might be expected to occur during the agricultural transition: *mechanization*, *increases in farm size*, and *crop/product diversification'* (Dawe, p.13, emphasis added). Dawe then reviews some statistical evidence to show how mechanization took place, farm size increased, and crop diversification took place in middle-income Asian countries, China, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. However, as Dawe did not define *AT* clearly, it is not obvious what sort of transformation is envisaged. For instance, farm size did not increase uniquely in different areas of these countries (Figures 14-15 on pp.20-21 in Dawe), but it is not evident whether this heterogeneity implies that *AT* took place in some parts of the country and did not in other parts. It is not clear either whether crop/product diversification took place consistently across these countries (e.g. Malaysia became more specialised in oil crops).

As the term suggests, 'transformation' should imply a fundamental change of the form of agriculture, rather than a simple change in production or surrounding environment or economy, which was not fully discussed by Dawe (2015). Barrett et al. (2017) focuses more on the efficiency of the agricultural sector from a broader perspective. They view the transformation essentially as the process whereby the agriculture becomes more efficient and productive. On the other hand, Ba et al. (1999, p.1) defined *AT* as a process in which (1) agriculture becomes increasingly reliant on input and output markets, (2) it integrates more fully with other sectors of the economy, and (3) local producers in the food system increasingly incorporate modern scientific knowledge into their practices. The first and the second aspects imply a greater exposure of the agricultural sector not only to the non-agricultural sector of the country but also to the rest of the world.

In this paper, following the literature, we define *AT* as fundamental changes in agricultural production leading to more efficient production which involves (i) changing cropping patterns with declining shares of grains and rising shares of non-grains, in particular, fruits, vegetables, dairy products, and meat, and (ii) a greater exposure to the agricultural sector and smallholders to the rest of the world, in particular, export markets. Our definition follows the theoretical literature of structural transformation, such as Reardon and Timmer (2014) who focus on diversification, commercialization, and scale of operations.

However, we also incorporate in our definition of *AT* the integration of factor market which has a close link with agricultural transformation (see Figure 1, p.109 of Reardon and Timmer).

III. Data

Following the discussions on Agricultural Transformation (*AT*) in the last section, this section will first provide our three measurements of *AT*. It will then discuss our measurement of SDGs. Finally, we will describe the data and the other variables used in our empirical analyses.

(1) Measurement of Agricultural Transformation

While *AT* encompasses various aspects and can be defined in different ways, given the data constraints, we will use the following three measures, namely, the commercialization index or the non-cereal share, agricultural openness and product diversification to capture salient features of *AT* following our definition of *AT* we provided in the previous section.

Commercialization Index or Non-Cereal Share

We use the FAOSTAT data to construct our commercialization index. The index is defined as the share of processed agricultural products, green vegetables, fruits and meat in the total agricultural products, including processed and primary products. A precise definition is given in Appendix 1. The main idea behind this index is that the crops or livestock that has been processed are more likely to be commercialised than primary crops or livestock[2] and that fruits and green vegetables are likely to be commercialised irrespective of the degree of processing. On the former, we assume, for instance, that farmers producing maize oil are more commercialised than those producing maize. While this will be a reasonable assumption, it is noted that our measure captures only a part of the processed agricultural products. For instance, we do not have the data of processed cereals (e.g. corn flakes). The index thus reflects the overall structure of agricultural production in terms of whether the agricultural crops or livestock are sold as raw crops or processed crops. To overcome the limitation, we include green vegetables, fruits and meat in the numerator given the fact these products can be commercialised easily without undergoing on-site processing.

To check the overall performance of the commercialisation index, we have examined the relationship between the commercialisation index and the index of mechanisation. Given that only crude measures are available from FAOSTAT, we have used the number of tractors per Land Area of $100km^2$. These variables are positively and significantly correlated with an overall correlation coefficient 0.19 for all developing areas. We have found that a positive association is the strongest for Asia where the coefficient of correlation is 0.42. A similar positive relationship between the two variables is found in both Latin America and Sub-Saharan Africa with the coefficient of correlation 0.30 and 0.18 respectively. As we will see later, in our cross-country panel estimations for all developing areas, the commercialisation does not have a statistically significant positive effect on agricultural productivity. To supplement this, we will construct the variable called 'Non Cereal share' (or Cereal Share), that is, the share of non-cereal product production in total agricultural value added. These two measures reflect the first dimension of our definition of *AT*, 'changing cropping patterns with declining shares of grains and rising shares of non-grains'.

Agricultural Openness

Agricultural openness is defined as the share of the aggregate agricultural export in the agricultural value added. Agricultural export is based on the trade file of FAOSTAT (http://www.fao.org/faostat/en/#data/TP) (in the international US$ (PPP) in 2004-2006). The agricultural exports include food and non-food agricultural product or exports. Here we do not include agricultural import because the import of agricultural crops, while influenced by globalisation and would influence agricultural production systems to some extent, would be mainly demand-driven and does not reflect the transformation of the agricultural production systems.[3] On the contrary, the higher share of agricultural export tends to reflect more integration of agricultural production into the rest of the world and is deemed a more suitable proxy for the agricultural transformation. The agricultural value added is based on World Development Indicator (WDI) in 2017. As the agricultural sector of the country gets structurally transformed (e.g. through mechanisation or contract farming), the relative competitiveness of the agricultural product improves and the agricultural openness index tends to be higher. We have examined the relationship between the agricultural openness index and the commercialisation index for all developing areas and for sub-regions. These two indices, as expected, are positively correlated with the coefficient of correlation 0.34 for all developing areas. This measure directly captures the second dimension in our definition of *AT*.

Product Diversification

We also use the diversity index at the country level drawing upon Remans et al. (2014) who used an index called 'Shannon Entropy diversity metric' to capture the product diversification at the country level using FAOSTAT. The index can be defined as:

$H' = -\sum_{i=1}^{R} p_i \ln p_i$

where R is the number of agricultural products and p_i is the share of production for the item i, available from FAOSTAT. The production share, p_i, is defined in terms of the monetary value at a local price for each product, i. If the country produces more agricultural products, including processed and unprocessed crops and the monetary values of products are more evenly divided among different items, the diversity index, H', takes a larger value. On the contrary, if the country produces a smaller number of agricultural products and the monetary value of one or two specific products is large, H' is smaller. The advantage of using this index is to simultaneously capture both how equally the country spreads agricultural production and how many products it produces. A limitation is that it does not take account of similarities of products in defining the diversity.

We have checked whether the product diversification index is positively associated with the commercialisation index. Contrary to our prediction, commercialisation is not significantly correlated with product diversification (the correlation coefficient: -0.11). A negative association is strong in Latin America than in Asia or Sub-Saharan Africa. This implies that the commercialisation may take place with specialisation, rather than diversification in some regions (e.g. Latin America). Given that our three measures of agricultural transformation are not strongly correlated and capture its different dimensions, they are inserted as explanatory variables at the same time.[4] We conjecture that the product diversification index partly captures the second dimension in our definition of *AT*.

(2) Measurement of SDGs

SDG 1

Our interest lies in examining how agricultural transformation helps the country achieve SDG 1 (ending poverty in all its forms everywhere), SDG2 (ending hunger, achieve food security and improved nutrition and promote sustainable agriculture), and SDG 10 (reducing inequality within and among countries).

On SDG 1, the specific target is set as 'By 2030, eradicate extreme poverty for all people everywhere, ***currently measured as people living on less than $1.25 a day***' (emphasis has been added by the author) among other goals (e.g. reducing at least by half the proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions).[5] Because it is not possible to use the 'all its dimensions' and also because the World Bank has replaced poverty data at $1.25 a day (2005 PPP) by those at $1.90 a day (2011 PPP) after the launch of SDGs in 2015, we will use the poverty headcount ratios at $1.90 and at $3.10 (2011 PPP), while supplementing them with the original measures for SDG 1, that is, poverty headcount ratios at $1.25 and at $2.00 (2005 PPP). We further use poverty headcount ratios at $1.25 and at $2.00 for rural and urban areas which were provided by Strategy and Knowledge Department (SKD), IFAD. A major limitation about international poverty measures (as well as hunger, food security and inequality measures) is that the data are highly unbalanced to reflect the years when household surveys (e.g. Living Standard Measurement Surveys) were conducted in each country. However, taking the five-year average will mitigate the problem of unbalance in the panel data. It is also noted that the cross-sectional coverage of poverty data (as well as the data on the Gini coefficient and child malnutrition) is fairly good (with more than 110 countries).

SDG 2

SDG2 stipulates the goals on food security, malnutrition, and agricultural productivity. For instance, they include the goals: 'By 2030, ending hunger and *ensure access by all people*, in particular the poor and people in vulnerable situations, including infants, to safe, nutritious and sufficient food all year round' (emphasis added by the author), 'By 2030, ending all forms of malnutrition, including achieving, by 2025, *the internationally agreed targets on stunting and wasting in children under 5 years of age*, and *addressing the nutritional needs of adolescent girls, pregnant and lactating women and older persons*' (emphasis has been added), and 'By 2030, *double the agricultural productivity* and incomes of small-scale food producers, in particular women, indigenous peoples, family farmers, pastoralists and fishers, including through secure and equal access to land, other productive resources and inputs, knowledge, financial services, markets and opportunities for value addition and non-farm employment' (emphasis has been added), among other sub-goals.[6] As it is impossible to deal with all the goals, we will focus on (i) agricultural TFP growth, (ii) malnutrition prevalence in terms of 'weight for age' and 'height for age' (% of children under 5), (iii) the prevalence of undernutrition (FAOSTAT), and (iv) food security indices, namely, 'Average dietary energy supply adequacy (%)'[7]. 'Average protein supply (g/capita/day)', 'Depth of the food deficit (kcal/capita/day)' and 'Prevalence of anaemia among pregnant women (%)'. The idea here is that we cover more than one dimension of food security, such as (i) food availability (dietary energy supply adequacy), (ii) food access (depth of food deficit), and (iii) utilization (child malnutrition indicators and prevalence of anaemia).

SDG 10

SDG10 is even more diverse than SDGs 1 and 2 and it is not easy to choose the variables for the empirical analysis. It stipulates the sub-goals as 'By 2030, progressively achieve and *sustain income growth of the bottom 40 per cent of the population at a rate higher than the national average*' (emphasis has been added by the author) following the World Bank arguments in discussion SDGs while the target year, 2015, was approaching (e.g. Dollar et al., 2016[8]). However, the coverage of the data is not good enough to use it as a main objective variable. Other sub-goals include: 'By 2030, empowering and promoting the social, economic and political inclusion of all, irrespective of age, sex, disability, race, ethnicity, origin, religion or economic or other status.'; 'Ensuring equal opportunity and reduce inequalities of outcome, including by eliminating discriminatory laws, policies and practices and promoting appropriate legislation, policies and action in this regard', 'Adopting policies, especially fiscal, wage and social protection policies, and progressively achieve greater equality' among other sub-goals. As these broad goals are rather qualitative or not easy to quantify by using the historical cross-country data, we will use the Gini coefficient at the national as well as sub-national levels (i.e. rural and urban areas), while supplementing the analysis by using income growth of the bottom 40 per cent of the population in a highly parsimonious specification.

(3) Data and Variables

Our empirical analysis is based mostly on FAOSTAT (http://faostat.fao.org/), World Development Indicators (WDI) 2017 (http://data.worldbank.org/data-catalog/world-development-indicators) and the World Bank poverty database (PovCalNet, http://iresearch.worldbank.org/PovcalNet/). These datasets have been widely used in the literature and their quality is deemed high, although there are some limitations for specific variables as we will discuss later. The agricultural total factor productivity (TFP) estimates are taken from Fuglie (2012 and 2015).[9]

Table 1 summarizes descriptive statistics of key variables in time-series and cross-sectional dimensions and their number of observations at regional levels to provide an idea of the data availability. Appendix 2 lists the names of countries, while further details of the data and definitions are provided in Appendix 3. We have structured the data as five-year average panel data to adjust the business cycle of the data following the empirical macro literature. Most of our variables are based on WDI and FAOSTAT, both of which aggregate micro-level household, labour force or industry survey data. As such, it is difficult to quantify the exact magnitude of measurement errors, it is conjectured that taking the five-year average will address the errors which occur randomly, while non-random errors (e.g. under-representativeness of the very poor in the informal sector, or under-reporting of income by the rich) cannot be addressed. As such, our results on SDGs will have to be interpreted with caution.

[Table 1 to be inserted around here]

As we will discuss in details, our main hypotheses are (i) whether agricultural transformation affects agricultural productivity directly and (ii) whether agricultural transformation indirectly reduces poverty, inequality or malnutrition indirectly through the agricultural productivity improvement. As we detailed in the previous section, the agricultural transformation is proxied by three measures, the commercialization index, the agricultural openness index and the product diversification index. We will proxy agricultural productivity by three variables, namely, (i) log of agricultural value added per worker, (ii) the first difference in log of agricultural value added per worker (that is, the growth rate of agricultural value added per worker), and (iii) the agricultural Total Factor Productivity (TFP). These are considered broad proxies for agricultural productivity of the country and deemed an appropriate proxy for one of the sub-goals SDG 2. Our main dependent variable, log agricultural value added per capita based on WDI has a good coverage of both time-series and cross-sectional dimensions, covering 7 five-year periods for 113 countries (Table 1). This is considered a broad measure of agricultural productivity in terms of monetary values of agricultural products to be produced per an agricultural worker. A limitation is that it is sensitive to sudden demographic changes in rural agricultural sectors, due to migrations. Our three AT variables and most of our variables have few missing observations in both time-series and cross-sectional dimensions, covering at least 7 five-year periods for more than 100 countries. However, the fragility index covers only 4 five-year periods and thus we have tried the cases with and without the fragility index. In case the fragility index is included (is excluded) in the model, the maximum correlation coefficient in absolute value is 0.50 (0.36), which will not cause any concerns for multicollinearity.[10]

Furthermore, we have compared the values of selected variables in the initial or early five years (1980-1984 for agricultural transformation or 1990-1994 for SDG variables) and the last five years to see the overall changes of these variables for both unbalanced and balanced panel data. Here the early periods are selected so that we have a reasonably large sample to make meaningful comparisons.[11] We have found that (i) both agricultural value added per worker and agricultural TFP significantly increased on average over the years (for both balanced and unbalanced panel), (ii) on AT variables agricultural openness and non-cereal share significantly increased on average, while the commercialization index and the product diversification remain broadly unchanged, and (iii) all the SDG variables – except poverty at US$1.9 a day (for the unbalanced panel), weight for age (for the balanced panel) and the Gini coefficient (for both) - significantly improved over time. This simple comparison is based on unconditional averages of the variables and ignores their dynamic changes or conditional factors and thus detailed investigations based on econometric estimations will be carried out in Section V.

Other Covariates

The degree of fragility is captured by 'fragility index' proxied by CPIA rating of macroeconomic management and coping with fragility (1=low to 6=high), which reflects a variety of indicators, observations, and judgments based on country knowledge and on relevant publicly available indicators. The high value implies low fragility and the low-value high fragility. We have also tried conflict indices, but prefer the 'fragility index' as the former does not cover many countries. We have used the annual growth rates of agricultural value added per worker based on Imai, Cheng, and Gaiha, (2017), drawing upon WDI.

We will use the unbalanced panel data for 105 developing countries (or its subset depending on the choice of explanatory variables) covering East/South East Asia and the Pacific, South Asia, East Europe and Central Asia, Middle East and North Africa, Sub-Saharan Africa, and Latin America and Caribbean, with a few robustness checks based on the balanced panel data.[12] We use the data since 1980 till 2015, but some covariate (e.g. fragility index) is available in 1990-2010 and so the number of years included in the regression varies depending on the specification. If the fragility index is dropped, the data cover nearly four decades. Although the data have some limitations arising from the fact that many variables from WDI and FAOSTAT were constructed by aggregating the micro-level data, they are deemed adequate for the objectives of our study.

VI. Empirical Models for Agricultural Transformation, Agricultural Growth and Poverty

The main purpose of our empirical model is to assess the effect of agricultural transformation (*AT*) on SDG 1 (poverty), SDG 2 (hunger, food security, and agricultural productivity) and SDG 10 (inequality). To do so, we will first estimate the effect of *AT* on agricultural productivity by treating the former as an endogenous variable. This is important because as the agricultural productivity improves, the degree of agricultural transformation is also influenced. We will then estimate the effect of the agricultural productivity on SDGs where agricultural productivity is estimated by *AT* in the first stage. Details of estimation strategies are provided below.

Estimation of Agricultural Productivity with Agricultural Transformation Indices

Given that the commercialisation index primarily influences agricultural productivity, we will first estimate agricultural value added per worker based on (1) pooled OLS, (2) fixed-effects (FE) and random-effects (RE) panel model, and (3) the dynamic panel model (or Blundell-Bond's (1998) linear dynamic panel model based on a system GMM). While agricultural transformation, regardless of its measurement (commercialisation index, agricultural openness, or agricultural product diversification), affects agricultural output or productivity, the process of agricultural transformation is likely to be accelerated by agricultural output or productivity. Given that agricultural transformation (*AT*) is likely to be endogenous when we estimate agricultural productivity, we apply system GMM by treating our proxies for *AT* as endogenous variables by using its own lagged variables in levels and differences as instruments.[13]

Model 1: Pooled OLS, FE or RE model for Agricultural Productivity

$$\boldsymbol{AG}_{it} = \beta_0 + \boldsymbol{AT}_{it-1}\beta_1 + \boldsymbol{X'}_{it-1}\beta_2 + \mu_i + \varepsilon_{it} \qquad (1)$$

For the five-year average panel, *t* stands for 1 (for 1976-1980), 2 (for 1981-1985), ... , 8 (for 2011-2015) covering the last four decades. *i* denotes countries (1, 2, ... , 105). $\boldsymbol{AG}_{it}$ is a dependent variable, an indicator of agricultural productivity. We use either (i) log agricultural value added per worker, or (ii) the first difference of log agricultural value added per worker as a proxy for $\boldsymbol{AG}_{it}$. We will take the lag of agricultural transformation indices given that the they are likely to be endogenous and using its values will partly mitigate the problem of endogeneity, while we will use IV or system GMM to address the issue more rigorously. Here $\boldsymbol{AT}_{it-1}$ indicates the first lag of a vector of agricultural transformation, namely, the commercialisation index (or in a few specifications, the share of cereal or non-cereal products in the total agricultural value added), the agricultural openness index, and the product diversification index. $\boldsymbol{X'}_{it-1}$ is a vector of explanatory variables: land area, population density, the fragility index, trade openness, and labour force with secondary education. μ_i is the country-specific unobservable term, such as, the institutional capacity or the cultural factor, influencing $\boldsymbol{AG}_{it}$. ε_{it} is an error term, independent and identically distributed (*i.i.d.*). This equation is estimated by either pooled OLS, FE or RE model. We will repeat the same regressions for a subset of the countries, Asia, Latin America and Caribbean and Sub-Saharan separately to see how the effects of $\boldsymbol{AT}_{it-1}$ are different for different regions.

Model 2: Dynamic Panel Model for Agricultural Productivity

$$\boldsymbol{AG}_{it} = \sum_{j=1}^{P} \alpha_j \boldsymbol{AG}_{it-j} + \sum_{k=0}^{Q} \beta_k \boldsymbol{AT}_{it-k} + \boldsymbol{X'}_{it}\gamma + \eta_i + \varepsilon_{it} \quad (2)$$

We will estimate this equation by system GMM (Arellano and Bover, 1995; Blundell and Bond, 1998) because (i) previous values of $\boldsymbol{AG}$ are likely to influence the present value of $\boldsymbol{AG}$ due to its persistence and (ii) $\boldsymbol{AT}$ is likely to be endogenous. Hence $\boldsymbol{AT}_{it-k}$ is treated as endogenous in the dynamic panel estimation.[14] The dynamic panel estimation based on the system GMM estimator explicitly models the dynamic realisation of agricultural transformation by having lagged dependent variables.[15] As an alternative to the standard first differencing approach[16], we can use the lagged differences of all explanatory variables as instruments for the level equation and combine the difference equation and the level equation in a system. Here the panel estimators use instrumental variables based on previous realisations of the explanatory variables as the internal instruments, using the Arellano-Bover and Blundell-Bond System GMM estimator with additional moment conditions.[17] Such a system gives a more consistent estimator under the assumptions that there is no second order serial correlation and the instruments are uncorrelated with the error terms. As a robustness check, in one case, we will add an external instrument, namely, a lagged value of transport equipment machinery, to capture the overall effectiveness and transaction costs in transporting or exporting goods from rural areas to cities or abroad.

We have repeated all the regressions at the regional levels (namely Asia, Latin America, and Sub-Saharan Africa). Given a small *n* and a relatively small sample size in this case, a finite sample correction has been made for the variance by using the robust estimator when two-step estimations are feasible (Windmeijer, 2005).

Model 3: Fixed-Effects IV Model for SDGs (Poverty, Malnutrition, Food Security, and Inequality)

First Stage:

$$\boldsymbol{AG}_{it} = \beta_0 + \boldsymbol{AT}_{it-1}\beta_1 + \boldsymbol{X'}_{it-1}\beta_2 + \mu_i + \varepsilon_{it} \qquad (3)$$

Second Stage:

$$\boldsymbol{SDG}_{it} = \gamma_0 + \widehat{\boldsymbol{AG}}_{it}\gamma_1 + \boldsymbol{X'}_{it-1}\gamma_2 + \vartheta_i + \varepsilon_{it} \qquad (4)$$

Here in order to make the estimation for SDG tractable[18], we will relax the assumption that $\boldsymbol{AT}_{it-1}$ is endogenous in the equation for $\boldsymbol{AG}_{it}$ in Model 2 (system GMM). We assume that, by taking the lag of $\boldsymbol{AT}$, namely agricultural commercialisation index, agricultural openness, and production diversity, $\boldsymbol{AT}_{it-1}$ is exogenous in Equation (3) and serve as instruments to identify the first-stage equation. In other words, following Imai, Gaiha, and Bresciani (2016) we will estimate the effect of $\boldsymbol{AT}$ on $\boldsymbol{SDG}$ only through increase in production of the agricultural sector per worker.

Whether $\boldsymbol{AT}_{it-1}$ serves as a valid instrument should be discussed for each goal in SDGs, *i.e.*, a dependant variable in the second stage. On poverty, while the literature suggests that a higher agricultural productivity or output leads to poverty reduction, it is unlikely for the increase in agricultural export, the increase in more processed crops or the increase in kinds of agricultural crops (keeping the agricultural production constant) to influence national, urban or rural poverty *directly*. This is because $\boldsymbol{AT}$ is the transformation of the agricultural sector, leading to increase productivity, but poverty is reduced as a result of changes in agricultural income/outputs, not as a result of the structural transformation itself. Of course, even without any change in the agricultural production or productivity, increasing the share of processed crops or livestock, shifting the domestic sale to export of crops, or introducing the new types of crops may lead to increase rural non-farm sector jobs and reduce poverty in the long run. However, in the short run, it is reasonable to assume that $\boldsymbol{AT}$ primarily and directly affects agricultural productivity ($\boldsymbol{AG}$) and its effect on poverty is realised only indirectly through the improvement in $\boldsymbol{AG}$. The validity of this assumption can be checked by specification tests. The same reasoning would apply when we estimate other goals in SDGs, such as rural or urban poverty, child malnutrition, food security indices and inequality. For instance, the overall food security could increase as a result of an increase in rural non-agricultural jobs due to the shift of domestic sales of crops to export, but this effect is indirect and is realised only in the long run.

Alternatively, in a few specifications, we estimate Equations (2) and (4) simultaneously. That is, in estimating Equation (4), we first derive the predicted value of $\boldsymbol{AG}_{it}$ ($\widehat{\boldsymbol{AG}}_{it}$) and those of the error term $\hat{\varepsilon}_{it}$ in Equation (2) and then put them in the fixed effects model where a variable in SDGs is estimated by those prediction terms and control variables where the standard errors are adjusted by bootstrapping. This is aimed to overcome the data limitations where some of the variables on SDGs are available for a limited number of years, while $\boldsymbol{AG}_{it}$ has a better coverage. The prevalence of undernutrition (POU) is estimated by the variables on agricultural transformation directly by the fixed effects model as $\widehat{\boldsymbol{AG}}_{it}$ is not statistically significant in the first stage of the FE-IV estimation outlined above.

V. Results

In this section, we will summarise and discuss the results derived for Models 1-3 for the five-year average panel data.[19]

(1) Results of Models 1-2: All Developing Areas

Table 2 shows the results on the effect of agricultural transformation indices on the level of agricultural value added per worker using the five-year average panel. Case 1 and Case 3 of Table 2 (pooled OLS and RE model) indicate that there is an overall positive and significant association between the commercialisation index and agricultural productivity (broadly defined as log agricultural value added per worker), while the agricultural productivity is negatively associated with product diversity in Case 1. Given that the commercialisation index is shown as the share (0 to 1) and that the left-hand-side variable is in the log, a 1% increase in the commercialisation in the previous year/period is associated with the 0.4%-1.4% increase in agricultural value added per worker. However, it is noted that the pooled OLS does not take account of the country unobservable effect and the RE model is not favoured over the FE model as the Hausman test is statistically significant. So we cannot make any claim on the causality between the two variables.

[Table 2 to be inserted around here]

The main conclusion that can be safely derived from Table 2 is that agricultural openness *causes* higher agricultural production per worker, a broad measure of agricultural productivity after taking into account the endogeneity of agricultural openness in Cases 4-8 of Table 2. This is suggested by statistically highly significant coefficient estimates of agricultural openness in these cases. In case of System GMM (Cases 4-8), a 1% increase in the agricultural openness leads to an increase in agricultural value added per capita by 0.04-0.05%.[20] The difference is due to the fact that the effect of lagged agricultural production is included in the latter. We have dropped the fragility index in Cases 6 and 7 of Table 2 and thus cover nearly four decades, while other cases cover only two decades. However, the sign and statistical significance of coefficient estimates for $\boldsymbol{AT}$ are similar in these cases. We can conclude that among three proxies for $\boldsymbol{AT}$, the agricultural openness is key to promoting agricultural productivity. On the results of control variables, we observe that, if the country is more fragile (or vulnerable), the agricultural value added per worker tends to be negatively affected.

Sensitivity tests are carried out in Cases 6-8 of Table 2. First, to see whether the initial differences in the agricultural development matters, we have carried a robustness check in Case 6 where the initial level of agricultural value added per worker (defined as the value in the earliest period during the first three periods in the case where the five-year average panel is used, or the value in the earliest year during the first 15 years for the annual panel). The initial level of agricultural development is positive and not statistically significant. This implies that the country which had already developed in agricultural productivity in early years tends to keep the high levels of agricultural productivity in later years. It is noted that an overall pattern of the results remains same, though the commercialisation index turns negative. In Case 7 we have used not only internal instruments but also an external instrument, that is, a lagged value of transport machinery. In Case 8 we have dropped the 26 countries with missing observations (71 observations) in Case 5 to make the panel balanced. The result does not change substantially.[21]

In Cases 5, 6, and 8 of Table 2, the commercialisation index has turned out to be negative and significant, which is somewhat puzzling given that we have hypothesised that commercialisation is one of the key features of agricultural transformation. One of the reasons is that, by the construction of the index with a focus on processed crops, fruits and green vegetables, the commercialisation index is negatively correlated with the share of cereal crops, which is sometimes important for the higher agricultural production. The coefficient of correlation based on our five-year panel data is 0.06. Barrett et al. (2017) have suggested that in Zambia maize and cereal output have doubled (with more than 50% increase in cereal yield) and poverty remained unchanged during the period between 2006 and 2011, while in Rwanda cereal output tripled and poverty reduced by 12% (45% of which due to an increase in agricultural productivity and marketing) from 2006 to 2011. So in some countries, the intensifications of cereal production appear to be key to productivity increase.

In Table 3 we have replaced the commercialisation index by the share of cereal production based on the five-year average panel and a system GMM (without the fragility index) for all developing areas, Asia, Latin America, and Sub-Saharan Africa. In Case 1 of

Table 3 for all developing areas, while agricultural openness remains positive and significant, cereal share is also *positive* and significant, implying that the higher cereal production will improve the broad measure of agricultural productivity in terms of log agricultural value added per worker. This is due to the positive effect of crop share in Sub-Saharan Africa and Latin America (Cases 3 and 4), while it is negative and significant for Asia (Case 2) where cereal production has become mature and shift to non-cereal production is more important. In disaggregated cases, agricultural openness is positive and significant only for Latin America, reflecting the possibility that the role of openness matters more in countries with higher GDP per capita and at a higher level of structural transformation. In all the regional regressions where system GMM is applied, standard errors are based on the robust estimator for the small sample in regional regressions (Windmeijer, 2005).

[Table 3 to be inserted around here]

One of the reasons why the share of cereals is positive for Latin America and Sub-Saharan Africa, while it is negative for Asia, is that the land abundance determines the extent to which cereal production contributes to the overall agricultural productivity in the long run, that is, the country with the relatively small arable land area cannot raise the productivity without relying on large land. To test this, we have inserted an interaction term of the land area and the share of lagged cereal production (as well as the cereal share and the land area) in Case 5. The result shows that the interaction is positive and statistically significant at the 1% level, while the coefficient estimate of the cereal share is positive and non-significant. This implies that the initial endowment of the country explains the role of cereal (or non-cereal share) as well as of the commercialisation index in determining the agricultural productivity.

As an extension we have tried a case where the dependent variable is *the growth* (rather than the level) of agricultural value added per worker, that is, the first difference of log of agricultural value added per worker for the five-year average panel based on the system GMM.[22] Consistent with the results in Table 2, if the share of agricultural export in agricultural value added of the country increases, the agricultural productivity increases. We can conclude that a 1% (or 10%) increase in the agricultural export share leads to the productivity growth by 0.04%-0.05% (or 0.4%-0.5%). On the contrary, the commercialisation index is negatively and significantly associated with the productivity growth. It is conjectured that only a shift from primary crops to processed crops or green vegetables/fruits may not lead to the productivity growth because there is a time lag for the new crop productions to get more productive (e.g. due to the initial fixed investment) or because cereal productions are sometimes more productive than non-cereal productions. We have also tested our earlier hypothesis by inserting the cereal share and the initial level of log agricultural value added per worker. First, the share of cereal products positively influences the growth of agricultural productivity. The initial level of log agricultural value added per worker, on the contrary, is positive and statistically insignificant. Inserting this term will not change the overall pattern of the coefficient estimates of other variables.[23]

(2) Results of Model 2: Asia, Latin America, and Sub-Saharan Africa

Given the possible heterogeneity of the effect of agricultural transformation on agricultural development, we applied the same model for Asia, Latin America and Caribbean, and Sub-Saharan Africa as presented in Table 4. Given the results in Table 3, we use the non-cereal share as an alternative to the commercialisation index. We find that in Asia agricultural openness *decreases* agricultural TFP growth in Case 3.[24] More importantly, the results in Cases 1 and 3 confirm that in Asia the non-cereal share increases not only log agricultural value added per capita but also the growth in agricultural TFP growth index defined by Fuglie (2012, 2015). The reason is unexpected, but it could reflect a negative association between the agricultural TFP growth index and log agricultural value added per worker in the negative range of the former (see Footnote 22).

The results on Latin America and the Caribbean are shown in the second panel of Table 4. For instance, if we focus on Case 4 in which the system GMM model is validated by AR tests and Sargan and Hansen tests, we find that *both* agricultural openness *and* product diversification increases our broad measure of agricultural productivity. That is, in addition to the role of openness, diversification of the agricultural product has a central role in increasing agricultural productivity in Latin America. However, the agricultural openness is negative and significant in Cases 6 and 7, to reflect the differences in the proxies for agricultural productivity.

The third panel of Table 4 reports the results for Sub-Saharan African countries. Consistent with previous results, agricultural openness is positively associated with both level and growth of the overall agricultural productivity. In Case 11, however, we find that agricultural openness promotes the growth of agricultural TFP. The non-cereal share and the product diversification index are mostly negative and significant for Sub-Saharan African countries, implying that specialisations at the aggregate level are important for promoting agricultural productivity in these countries with comparatively lower GDP per capita.

[Table 4 to be inserted around here]

That is, for Sub-Saharan Africa, it would be crucial for policymakers to specialise certain crop productions, such as cereals, to improve the efficiency through the economies of scale, and focus on increasing the share of agricultural export in the total agricultural production. [25]

(3) Results of Model 3: SDG 1

We now apply the FE-IV model for both five-year average panel in Table 5.[26] The model consists of the two stages: the first stage where log agricultural value added per worker is estimated by our three measures of agricultural transformation, namely, the commercialisation index, the agricultural openness index, and the product diversification index (instruments) with control variables and the second stage where the poverty headcount ratio is estimated by log of agricultural value added per worker that was estimated in the first stage. The objective variables are poverty headcount ratios at US$1.9 or US$3.1 a day (2011 PPP) at national levels (Cases 1-2 of Table 5) or US$1.25 or US$2 a day (2005 PPP) at the national level, or at rural or urban areas (Cases 3-8 of Table 4). In the first stage agricultural openness is positive and significant in all the cases in Table 4, while the commercialisation is significant in Cases 1-4 and the product diversification index is significant in Cases 5-8. Sagan test together with Stock-Yogo test implies that the instruments are valid in all the cases except Case 8.

[Table 5 to be inserted around here]

The estimates of the elasticity of poverty with respect to agricultural openness (evaluated at the mean of the poverty headcount ratio) are shown at the bottom of Table 5. The first conclusion is that agricultural openness tends to reduce poverty more strongly at the higher poverty thresholds. In other words, the poverty reducing effects at the lower poverty thresholds are limited. Second, based on the five-year average panel data, a 1% increase in the agricultural openness tends to reduce poverty ay by 0.062% to 0.188% at higher poverty thresholds and by 0.03% to 0.06% at the lower thresholds, though the latter are not statistically significant. These are not high at first sight, but poverty-reducing effects are likely to be substantial as the effects will be accumulated over the years. Thirdly, agricultural openness is likely to reduce both rural and urban poverty, with the absolute magnitude of reduction larger for rural poverty. We conclude that the agricultural transformation, proxied by the agricultural openness, has a significant poverty-reducing effect. We have used the poverty headcount ratios, but similar conclusions have been obtained for poverty gap measures. In terms of policy implications, it is important for policymakers to facilitate agricultural export directly by removing tariff and non-tariff barriers, or indirectly by investing rural or transport infrastructure to reducing transaction costs, in order to improve the overall agricultural productivity and eradicate extreme poverty.

(4) Results of Model 3: SDG 2

As we have already examined the effects of agricultural transformation indices on agricultural productivity in details, we will estimate the effects of agricultural transformation indices on child malnutrition, undernutrition and food security. The same model, namely, the FE-IV model is used except the case where the prevalence of undernutrition is estimated as the predicted value of the log of agricultural value added is not statistically significant in the second stage. The results are reported in Table 6.

Stock-Yogo test and Sargan test validate our instruments in terms of the relevance and the exclusion restriction except for Cases 4-6 where the F-statistics are lower than the Stock-Yogo threshold. In Table 6, the agricultural openness is positive and significant in the first stage and log agricultural value added per worker is negative and significant in all the cases. As before, the elasticity estimates are reported at the bottom of Table 6. It is found that an increase in agricultural openness significantly reduces the prevalence of underweight. A 1% increase in the agricultural openness leads to 0.038% reduction in the rate of prevalence of child underweight evaluated at its mean, other factors being equal. Likewise, a 1% increase in the commercialisation index leads to 0.013% reduction in the rate of prevalence of child underweight.

[Table 6 to be inserted around here]

We also found that a 1% increase in the agricultural openness on average leads to 0.098% reduction in the rate of prevalence of stunting evaluated at its mean, other factors being equal. We have also confirmed that if agricultural sector is more open to the rest of the economy, food security is likely to improve in a number of dimensions, such as energy supply adequacy, protein supply and (lack of) food deficit and the rate of pregnant women who suffer from anaemia. In the final column, the result is presented on the prevalence of undernutrtion (POU). It is found that if agricultural openness increases by 1%, the POU tends to decrease by 0.006. However, the result should be interpreted with caution as it is not statistically significant.

(5) Results of Model 3: SDG 10

Next, we have estimated the effects of agricultural transformation on inequality (SDG 10) using the Gini coefficient at national, rural and urban levels as well as welfare growth rate of the bottom 40% in Table 7. While the FE-IV model is applied to the Gini coefficient, a simple single univariate model is used for the growth of the bottom 40% of the population. Instruments have been validated in all the cases in terms of the instrument relevance test (Stock-Yogo test) and the test for exclusion restrictions (Sargan Test).

[Table 7 to be inserted around here]

Table 7 shows that one of the instruments, agricultural openness is positive and significant in the first stage in all the cases where FE-IV model is applied, while log agricultural value added per worker is negative and significant in the second stage regression for the Gini coefficient. The combined elasticity estimates are shown at the bottom of Table 7. A 1% increase in the agricultural openness corresponds to 0.028% decline in the national Gini, 0.03% decline in the rural Gini and 0.027% decline in the urban Gini. This appears not to be large at first sight, but cumulative effects could be substantial. That is, the agricultural transformation is found to have a substantial inequality-reducing effect.

However, we have found a *negative* and significant relationship between log agricultural value added per worker and the welfare growth rate of bottom 40%. That is, agricultural growth tends to deter the welfare growth of bottom 40%. Given that the main determinant of agricultural value added per worker is agricultural openness, we can infer that agricultural transformation in terms of increased openness of the agricultural sector to the rest of the world would increase inequality once we focus on the growth rate of bottom 40%. However, because this is a crude measure of inequality that ignores the distribution among the bottom 40%, we would place more importance on the results which confirm inequality-reducing effects of agricultural transformation when the Gini coefficient is applied.

We have confirmed that the agricultural openness is significantly associated with improvement in a number of measures in SDGs 1, 2 and 10. However, a caveat is that not all the countries have been successful in increasing the agricultural openness. In most of the countries in Latin America and Sub-Saharan Africa, the index increased only gradually. Overall, the agricultural openness index increased by 1.7% annually (by 1.0% for Asia, 3.1% for Latin America and by 1.1% for Sub-Saharan Africa). But this average masks the heterogeneity across different countries as while some countries have managed to increase the agricultural openness greatly, agricultural openness remained unchanged in some countries. For instance, Botswana (South Africa) increased the agricultural openness by 5.8% (2.9%) annually, while it was stagnant in other SSA countries. In Asia, Malaysia or Vietnam has had a high growth rate in the agricultural openness (3.3% and 2.9% respectively), but the increase is slow in South Asian countries. Hence how the country changes the export structure strategically is key to embodying a positive effect of the agricultural openness on SDGs.

(5) Results of Model 3: SDG 1 and 2 at regional levels

To see how other indices affect SDGs, we have estimated the Model 3 where in the first stage the dynamic model is used and in the second the fixed effects model is applied by using the predicted values of log agricultural value added and the error term with standard errors bootstrapped. This is carried out for selective cases of regional regressions for Asia, Latin America, and Sub-Saharan Africa where insightful results are obtained in the first stage.[27]

We have found that for Asia the lagged share of non-cereal production significantly reduces poverty headcounts at US$3.10 and US$1.90 as well as the prevalence of stunting and underweight. For instance, a 1% increase in the lagged share of non-cereal production reduces poverty at US$3.10 by 0.12%. In Latin America, on the other hand, the product diversification index significantly reduces the poverty headcount at US$3.10. A 1% increase in the diversity index leads to, on average, 0.085% decline in the poverty headcount at US$3.10. While this is larger than the effect of the agricultural openness (0.0074%), we avoid comparing the estimates across different measures of agricultural transformation as a 1% change has a different meaning according to which index we focus on. In Sub-Saharan Africa, though the estimates are statistically insignificant, an increase in the cereal share is likely to decrease poverty, the results which are in sharp contrast with those for Asia.

VI. Concluding Remarks and Policy Implications

This paper has analysed the role of the transformation of the rural agricultural sector (or 'agricultural transformation' in short) in achieving Sustainable Development Goals (SDGs) 1, 2 and 10 drawing upon the cross-country panel data over the past four decades for 105 developing countries. Agricultural transformation has been featured in recent years as an important change in the agricultural sector and in the rural economies of developing countries as the rural agriculture sector has become closely linked to not only the non-agricultural or industrial sector of the country and the rapidly-growing urban sector of the country but also the agricultural and non-agricultural sectors of both developed and developing countries.

The process of agricultural transformation is diverse and it is not straightforward to quantify it in a meaningful way. So we define agricultural transformation by three different indices, namely, (i) the agricultural openness index - the share of agricultural export in agricultural value added of the country, (ii) the commercialization index - the share of processed agricultural products, fruits, green vegetables, and meats in all primary and processed agricultural products, and (iii) the product diversification index to capture the extent to which the country diversify the agricultural production.

Agricultural development has been considered to be important for poverty reduction, but it remains unclear whether agricultural transformation influences agricultural development and poverty, SDG 1. Also important yet unclear is whether and the extent to which agricultural transformation would reduce hunger, malnutrition and food security (SDG 2) and inequality (SDG 10). Our study is important because, as far as we know, this is the first study to quantify the agricultural transformation - even in a limited manner - and evaluate its effect on agricultural productivity and SDGs. Methodologically, not only the dynamic nature of agricultural production but also the endogeneity of agricultural transformation is taken into account by the model of system Generalized Method of Moments (system GMM).

First, we have found that transformation of the agricultural sector proxied by the agricultural openness index has dynamically increased the broad measure of agricultural productivity (in terms of agricultural value added per worker) and its growth and has consequently reduced national, rural and urban poverty significantly. However, the poverty-reducing effects of the agricultural transformation are relatively larger at the higher poverty thresholds (US$3.1 per day (2011PPP) and US$2 per day (2005PPP)) than at the lower poverty thresholds (US$1.9 per day (2011PPP) and US$1.25 per day (2005PPP)) for both poverty headcount and poverty gap measures. So there is a possibility that the moderately poor benefit more than the extremely poor from the process of agricultural transformation.

Our results may be driven by a cluster of countries with relatively high growth in both agricultural openness and agricultural productivity and so the results will have to be interpreted with caution given that it may not be straightforward to the country increases agricultural openness in a short period.

Second, agricultural openness is negatively associated with child malnutrition in terms of underweight and stunting, improves food security measures, such as the indices of energy supply adequacy, protein supply, depth of food deficit and the prevalence of anaemia among pregnant women.

Third, the agricultural openness tends to reduce the Gini coefficient at both national and subnational levels (for both rural and urban areas), while it is likely to *deter* the welfare growth of the bottom 40%. So we have good evidence to support the claim that agricultural transformation in terms of agricultural openness helps achieve SDG 1 (poverty reduction), SDG 2 (reducing hunger and malnutrition, improving food security, and doubling agricultural productivity) and SDG 10 (reducing inequality).

Fourth, whether more commercialisation in terms of the higher share of processed crops, fruits and green vegetables improves agricultural production depends on the specifications and geographical regions. For instance, if we use pooled OLS or random effects model, the higher commercialisation index is associated with higher agricultural value added per worker. Also, in Latin America where the agricultural sector is more mature than other regions, commercialisation tends to improve agricultural TFP. In a few cases the commercialisation index is negative and significant. This could be due to the fact that fact that the higher commercialisation captures the lower share of cereal production. In one case, the higher share of cereal crops – together with agricultural openness – was found to increases log agricultural value added per worker (particularly in Sub-Saharan Africa and Latin America).

Fifth, product diversification, contrary to our expectation, reduces agricultural productivity in a number of cases. This is likely to be due to the fact that the economies of scale of agricultural production are often important in raising the country's agricultural productivity. Also, if similar crops are produced in a large area of the country, positive effect on productivity due to learning from one region to another, or competition across different regions is greater. For instance, among Asian countries, Malaysia has achieved a higher agricultural productivity with the low product diversification (Imai, Gaiha, and Bresciani, 2016). However, among Latin American countries, product diversification was found to increase agricultural productivity.

Our study has a number of policy implications. First, agricultural productivity growth, for instance, through higher agricultural openness will help developing countries achieve SDG 1 (poverty reduction), SDG 2 (alleviation of malnutrition and hunger; securing food security), and SDG 10 (reduction of inequality). Because SDG 2 includes doubling agricultural productivity, our analysis suggests a win-win solution where the facilitation of agricultural trades, for instance, through promoting regional economic integrations, reducing transaction costs such as tariff and non-tariff barriers, would improve agricultural productivity and address other SDG goals of poverty, hunger and inequality. However, if the country's agricultural openness has become already high (e.g. Thailand, Vietnam), there is no scope for increasing the agricultural openness and a policy is crucial to further increase the agricultural productivity or directly support the poor. If the country's agricultural openness is low, it can increase the agricultural productivity by promoting the agricultural export, which could indirectly improve SDG measures. However, it should be noted that the effects of agricultural openness on SDGs are *indirect*. What is crucial is for the country to choose a set of policies to maximise agricultural productivity (where increasing the openness is only one of the potential choices) in order to achieve SDGs.

Second, our paper shows that agricultural transformation is likely to improve agricultural productivity, which would reduce both moderate poverty and extreme poverty. However, the poverty-reducing effect is higher for the former. It is noted here that agricultural transformation itself does not have any distributional effect. Agricultural productivity improvement will bring about benefits for the moderate poor, rather than the extreme poor, because the latter may be left out of the process of accessing the new technologies, infrastructure, or other opportunities for agricultural transformations. Under these circumstances, a policy is still important to support the poorest while the rural agricultural sector undergoes a transformation. Also, given that there is a negative correlation between the agricultural value added per worker and the welfare growth of the bottom 40%, the eventual/indirect distributional impact of policies promoting the process of agricultural transformation should be carefully monitored.

Third, our results suggest that product specialisation is important for improving agricultural productivity, except for Latin America.[28] This could be related to other findings of the current study, such as an important role of agricultural openness - where the neo-classical trade theory implies higher efficiency through specialisations - as well as the importance of cereal production in improving overall productivity. Depending on the stage of agricultural development, facilitating the production and exporting of cereal crops will increase the agricultural productivity, while at the higher level of development (e.g. Latin America), product diversification would increase agricultural productivity.

Finally, if efficiency though the economies of scale is important - suggested by the roles of product specification (which are implied by negative coefficient estimates of product diversifications in several cases e.g. in Tables 3 and 4) - there is a case for promoting synergy between public and private investment in rural areas and for improving the quality of rural infrastructure. A priority is to strengthen rural infrastructure. Our results suggest that the transformation process incorporating poor smallhoders through easier access to credit, land and output markets leads to poverty and inequality reduction. As prospects of absorption of growing rural labour force in manufacturing and services and other activities are limited, job expansion in rural areas is imperative. Some of the preceding proposals would help create more employment in rural areas, raise wage rates and dampen rural-urban migration. Land rental markets would facilitate the redistribution of land in favour of more efficient small farmers and help consolidation of small farms into more viable units.

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Table 1 Descriptive statistics of key variables in time-series and cross-sectional dimensions and their number of observations at regional levels

Variable	Source		Mean	Std. Dev.	Min	Max	Observations			
							overall	Asia	Latin America	SSA
Agriculture value added per worker (first difference)	WDI	Overall	7.58	1.20	4.94	12.43	776	138	171	288
(constant 2010 US$)		between (cross-section)		1.19	5.38	11.40	113	20	22	41
		within (time)		0.29	6.56	8.60	7	7	8	7
		Available time periods					**1980-2014**			
Agriculture value added per worker (first difference of log) (constant 2010 US$)	WDI	Overall	0.10	0.14	-0.44	0.52	663	118	149	247
		Between		0.10	-0.11	0.51	112	19	22	41
		Within		0.10	-0.41	0.65	6	6	7	6
		Available time periods					**1985-2014**			
Agricultural TFP Index growth	Fuglie, 2012	Overall	0.01	0.02	-0.14	0.15	1229	228	242	484
		Between		0.01	-0.01	0.03	113	21	22	44
		Within		0.02	-0.14	0.15	11	11	11	11
		Available time periods					**1961-2014**			
Commercialisation Index	FAOSTAT	Overall	0.68	0.18	0.17	0.99	1265	231	242	462
		Between		0.17	0.26	0.99	115	21	22	42
		Within		0.04	0.33	0.93	11	11	11	11
		Available time periods					**1961-2014**			
Agricultural Openness	FAOSTAT	Overall	0.36	0.82	0.00	13.17	831	156	197	316
		Between		0.69	0.03	5.39	108	19	21	40
		Within		0.55	-3.27	8.15	8	8	9	8
							1975-2014			
Product Diversification	FAOSTAT	Overall	2.54	0.49	0.27	3.40	1265	231	242	462
		Between		0.48	0.53	3.27	115	21	22	42
		Within		0.09	2.08	2.83	11	11	11	11
							1961-2014			
Land Area	WDI	Overall	758.00	1923	0.46	16400	1410	246	276	516
		Between		1927	0.46	16400	118	21	23	43
		Within		4.70	702.40	803	11	11	11	11
							1961-2014			
Population Density	WDI	Overall	75.49	105.33	0.78	1245.11	1404	246	276	516
		Between		97.51	1.77	816.21	118	21	23	43
		Within		40.04	-342.62	504.39	11	11	11	11
							1961-2014			
Fragility Index	WDI	Overall	11.22	5.88	0.00	23.80	446	78	84	168
		Between		5.73	0.25	23.25	113	20	21	42
		Within		1.47	6.94	15.45	**4**	**4**	**4**	4
							1961-2014			
openness	WDI	overall	70.26	36.79	4.30	229.64	1109	193	255	438
		between		32.18	19.42	147.10	117	21	23	42
		within		18.97	-12.65	173.92	9	9	11	10

							1975-2014			
Labour force	WDI	overall	0.73	0.42	0.00	1.00	1428	252	276	528
with secondary		between		0.38	0.07	1.00	119	21	23	44
Education		within		0.18	0.37	1.58	12	12	12	12
							1980-2014			
povertyhc $3.1	WDI	overall	38.60	30.79	0.00	98.35	483	100	115	137
		between		29.71	0.07	94.53	112	21	23	43
		within		9.74	-6.56	75.18	4	5	5	3
							1980-2014			
povertyhc $1.9	WDI	overall	23.09	24.30	0.00	94.05	483	100	115	137
		between		23.95	0.03	85.57	112	21	23	43
		within		8.96	-13.12	62.07	4	5	5	3
							1980-2014			
Weight for age	WDI	overall	17.56	13.00	0.50	67.30	484	94	117	193
		between		11.98	0.60	51.98	111	20	23	44
		within		4.78	-2.38	36.99	4	5	5	4
							1980-2014			
Gini	WDI	overall	40.82	9.18	19.40	74.33	646	125	144	196
		between		7.83	25.69	56.31	119	21	23	44
		within		4.21	25.24	59.65	5	6	6	4
							1980-2014			

Table 2 Effects of Agricultural Transformation on the Level of Agricultural Value Added per capita (Five-Years Average Panel)

Dep. Variable	log agricultural value added							
Regions	All Developing Areas							
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
EXP. VARIABLES	Pooled OLS	FE	RE	SGMM	SGMM	SGMM With an initial value	SGMM With an external IV	SGMM Balanced panel
log Agricultural Value Added per worker, an initial value						0.0104		
						[1.523]		
Commercialization Index (-1)	1.386***	-0.127	0.443*	-0.155	-0.364***	-0.263***	0.124	-0.364***
	[4.503]	[-0.423]	**[1.647]**	[-1.101]	[-3.225]	[-9.636]	[1.239]	[-3.225]
Agricultural Openness(-1)	-0.0121	0.0430**	0.0464**	0.0422***	0.0491***	0.0432***	0.0389***	0.0491***
	[-0.194]	**[2.185]**	**[2.294]**	**[6.105]**	[16.55]	[5.426]	[10.27]	[16.55]
Product Diversity(-1)	-0.281***	-0.00207	-0.0998	-0.0181	-0.0627	0.0202*	-0.00265	-0.0627
	[-2.600]	[-0.0141]	[-0.821]	[-0.283]	[-1.222]	[1.732]	[-0.0402]	[-1.222]
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Number of lags of dependent variables in the right hand side	**0**	**0**	**0**	**2**	**2**	**2**	**2**	**2**
Observations	370	370	370	244	417	417	195	346
R-squared	0.522	0.259						
Number of countries		102	102	92	96	96	64	70
AR(1) in first difference (Pr > z)				0.038**	0.001***	0.038	0.001	0.001
AR(2) in first difference (Pr>z)				0.148	0.08*	0.148	0.08	0.08
Sargan statistic								
Over identification tests								
Sargan Test (Chi2)				6.03	6.03	28.7	28.7	21.74
Prob > chi2				**0.813**	**0.052**	**0.052**	**0.244**	**0**
Hansen Test (Chi2)				**6.48**	**6.48**	28.78	28.78	19.83
Prob > chi2				**0.774**	**0.051**	**0.051**	**0.343**	**0.078**
Breusch and Pagan Lagrangian multiplier test for random effects								
chibar2(01) =			435.57***					
Prob > chibar2 =			0					
Hausman Test (chi2(7))		29.27						
Prob>chi2 =		0.0001						

Notes: t-statistics in brackets (*** p<0.01, ** p<0.05, * p<0.1). System GMM is based on the two-step robust estimators. Control variables are Land area, Population Density, Fragility Index, Trade Openness, and Labour Force with Secondary Education. Same control variables will be used in Tables 3-8.

Table 3 Effects of Cereal Share on the Level of Agricultural value added per worker

Dep. Variable	log agricultural value added				
Regions	All developing areas	Asia	Lain America	SSA	All developing areas
Data	Five-Years Average Panel				
	Case 1	Case 2	Case 3	Case 4	Case 5
EXP. VARIABLES	SGMM	SGMM	SGMM	SGMM	SGMM
Cereal Share (-1)	**0.195***	**-0.225****	**0.371****	**0.702*****	0.155
	[1.684]	**[-2.650]**	**[2.161]**	**[2.994]**	[1.272]
Cereal Share (-1)*Land					**2.12e-08*****
					[2.826]
Agricultural Openness (-1)	0.0535***	0.170	0.0619***	0.115	0.0539***
	[8.506]	[1.463]	[6.529]	[1.348]	[8.685]
Production Diversity	-0.121	0.0709	-0.663***	0.138	-0.127*
	[-1.629]	[1.003]	[-7.004]	[1.527]	[-1.688]
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Number of lags of dependent variables in the right hand side	**2**	**2**	**2**	**2**	**2**
Observations	325	61	80	124	325
Number of country	95	17	21	32	95
AR(1) in first difference (Pr > z)	0	0.994	0.03	0	0
AR(2) in first difference (Pr>z)	0.118	0.723	0.538	0.087	0.134
Over identification tests					
Sargan Test (Chi2)	10.04	21.55	7.7	20.33	10.09
Prob > chi2	**0.612**	**0.723**	**0.808**	**0.061**	**0.608**
Hansen Test (Chi2)	10.79	10.75	9.05	14.14	10.69
Prob > chi2	**0.574**	**0.55**	**0.698**	**0.528**	**0.556**

Notes: t-statistics in brackets (*** p<0.01, ** p<0.05, * p<0.1). Standard errors are based on the robust estimator for the small sample in regional regressions (Windmeijer, 2005).

Table 4 Regional Disaggregation: Effects of Agricultural Transformation on Agricultural Productivity

Dep. Variable	log Agricultural VA per capita	D.log Agricultural Value Added per worker	Agricultural TFP Growth	log Agricultural VA per capita	Dlog Agricultural VA per capita	Agricultural TFP growth		log Agricultural VA per capita	D.log Agricultural Value Added per worker	Agricultural TFP Growth	D Agricultural TFP growth
Regions	**Asia**			**Latin America**				**Sub-Saharan Africa**			
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8	Case 9	Case 10	Case 11
EXP. VARIABLES	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM	SGMM
Non Cereal Share(-1)	**0.225****	-0.0546	**0.0583*****	-0.197	0.0996	**0.165*****	-0.00453	**-0.494*****	**-0.498*****	**-0.0805*****	**-0.0610***
	[2.650]	[-0.516]	**[2.890]**	[-0.696]	[0.274]	**[2.937]**	[-0.0981]	**[-2.957]**	**[-3.569]**	**[-3.484]**	**[-1.756]**
Agricultural Openness(-1)	0.170	0.0244	**-0.0276****	**0.0500*****	**0.0426*****	**-0.00184****	**-0.00208*****	**0.166****	**0.177***	0.0188	**0.0494*****
	[1.463]	[0.345]	**[-2.213]**	**[4.561]**	**[5.665]**	**[-2.665]**	**[-7.205]**	**[2.378]**	**[1.854]**	[1.298]	**[3.002]**
Production diversification (-1)	0.0709	-0.0316	-0.00607	**0.247***	**0.328*****	0.0278	0.0135	**-0.384*****	**-0.385*****	-0.0135	-0.00541
	[1.003]	[-0.808]	[-0.465]	**[1.916]**	**[3.033]**	[0.995]	[0.876]	**[-3.365]**	**[-2.921]**	[-1.232]	[-0.301]
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Number of lags of dependent variables in the right hand side	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**
Observations	61	43	51	58	56	60	148	91	90	93	93
Number of countries	17	17	18	20	20	20	21	31	31	33	33
AR(1) in first difference (Pr > z)	0.944	0.747	0.182	0.199	0.036	0.172	0.01	0.037	0.06	0.052	0.042
AR(2) in first difference (Pr>z)	0.723	0.189	0.636	0.067	0.768	0.239	0.596	0.458	0.83	0.426	0.967
Sargan Test (Chi2)	21.55**	18.07**	31.95*	12.57	6.59	30.97	52.2	18.10*	16.45**	50.87***	28.88*
Prob > chi2	0.043	0.012	0.078	**0.199**	**0.472**	**0.097**	**0.135**	0.053	**0.021**	**0**	**0.068**
Hansen Test (Chi2)	10.75	6.66	7.61	12.75	12.49	9.53	13.51	9.2	15.00**	25.6	22.51
Prob > chi2	0.55	0.465	0.998	**0.238**	**0.085**	0.99	1	**0.513**	**0.036**	**0.269**	**0.259**

Notes: t-statistics in brackets (*** p<0.01, ** p<0.05, * p<0.1). Standard errors are based on the robust estimator for small sample in regional regressions for the dynamic panel estimations (Windmeijer, 2005)

Table 5 SDG 1: Effects of Agricultural Transformation on Poverty

Dep. Variable	Poverty HC USD3.10	Poverty HC USD1.90	Poverty HC USD2.00	Poverty HC USD1.25	Rural Poverty HC USD2.00	Rural Poverty HC USD1.25	Urban Poverty HC USD2.00	Urban Poverty HC USD1.25
Regions	All Developing Areas							
Data	Five Year Average Panel							
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7	Case 8
EXP. VARIABLES	IV	IV	IV	IV	IV	IV	IV	IV
FIRST STAGE								
Dep. Variable	log Agricultural value added per worker				log Agricultural value added per worker			
Commercialization Index								
L1.	**-0.682****	**-0.682****	**-0.697****	**-0.697****	-0.424	-0.424	-0.424	-0.424
	[-2.00]	**[-2.00]**	**[-2.01]**	**[-2.01]**	[-1.05]	[-1.05]	[-1.05]	[-1.05]
Agricultural Openness								
L1.	**0.386*****	**0.386*****	**0.787*****	**0.787*****	**0.460*****	**0.460*****	**0.460*****	**0.460*****
	[7.40]	**[7.40]**	**[7.29]**	**[7.29]**	**[8.59]**	**[8.59]**	**[8.59]**	**[8.59]**
Product diversification								
L1.	-0.027	-0.027	-0.121	-0.121	**-0.452*****	**-0.452*****	**-0.452*****	**-0.452*****
	[-0.19]	[-0.19]	[-0.82]	[-0.82]	**[-2.68]**	**[-2.68]**	**[-2.68]**	**[-2.68]**
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
	Poverty HC USD310	Poverty HC USD190	Poverty HC USD200	Poverty HC USD125	Rural Poverty HC USD200	Rural Poverty HC USD200	Urban Poverty HC USD200	Urban Poverty HC USD200
VARIABLES	Poverty HC USD3.10	Poverty HC USD1.90	Poverty HC USD2.00	Poverty HC USD1.25	Rural Poverty HC USD2.00	Rural Poverty HC USD1.25	Urban Poverty HC USD2.00	Urban Poverty HC USD1.25
log Agricultural Value Added per worker	**-0.162*****	-0.079	**-0.239*****	-0.079	**-0.2398*****	**-0.151*****	**-0.1471*****	**-0.0832****
	[-2.875]	[-1.386]	**[-3.922]**	[-1.247]	**[-4.265]**	**[-2.736]**	**[-3.050]**	**[-1.996]**
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	371	371	326	326	224	224	224	224
R-squared	0.373	0.265	0.286	0.123	0.351	0.333	0.305	0.193
Number of country	85	85	83	83	74	74	74	74
F test of excluded instruments	F(3, 279) =	F(3, 279) =	F(3, 236) =	F(3, 236) =	F(3, 143) =	F(3, 143) =	F(3, 143) =	F(3, 143) =
	19.79***	19.79***	19.09***	19.09***	26.40***	26.40***	26.40***	26.40***
Prob > F =	0	0	0	0	0	0	0	0
Sargan statistic (over identification test of all instruments)	1.459	3.743	0.722	3.389	3.879	4.263	3.864	**6.664****
Chi-sq(2) Pvalue	**0.482**	**0.154**	**0.697**	**0.184**	**0.144**	**0.119**	**0.145**	**0.036**
Elasticity Estimates								
VARIABLES	Poverty HC USD3.10	Poverty HC USD1.90	Poverty HC USD2.00	Poverty HC USD1.25	Rural Poverty HC USD2.00	Rural Poverty HC USD1.25	Urban Poverty HC USD2.00	Urban Poverty HC USD1.25
∂Poverty HC /∂ log agrivapw	**-0.16*****	-0.0785	**-0.239*****	-0.079	**-0.2398*****	**-0.151*****	**-0.147*****	**-0.8323****
∂log agrivapw /∂ Ag Openness	**0.386*****	**0.386*****	**0.787*****	**0.787*****	**0.460*****	**0.460*****	**0.460*****	**0.460*****
∂ Poverty HC /∂Ag openness	**-0.062*****	-0.030	**-0.188*****	-0.062	**-0.110*****	**-0.069*****	**-0.068*****	**-0.038*****

z-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 6 SDG 2: Effects of Agricultural Transformation on Hunger and Food Security (based on Five Year Average Panel)

Dep. Variable							
Regions	The prevalence of underweight	The prevalence of stunting	Energy_Supply_Adequacy	Protein_Supply	Depth_Food_Deficit	Anaemia_during_Pregnancy	Prevalence of under nutrition
Data	Five Year Average Panel						
	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6	Case 7
EXP. VARIABLES	IV						FE
FIRST STAGE							
Dep. Variable	log Agricultural value added per worker						
Commercialization Index							
L1.	**-0.066**	**-0.359**	**-0.369**	**-0.389**	**0.239**	**-0.262**	-
	[-0.18]	**[-0.95]**	**[-1.14]**	**[-1.15]**	**[0.67]**	**[-0.83]**	-
Agricultural Openness							
L1.	**0.525*** **	**0.504*** **	**0.075*** **	**0.046*** **	**0.022*** **	**0.047*** **	-
	[6.95]	**[6.56]**	**[4.52]**	**[2.23]**	**[1.34]**	**[2.25]**	-
Product Diversification							
L1.	**-0.092**	**-0.129**	**-0.224**	**-0.103**	**-0.323**	**-0.007**	-
	[-0.67]	**[-0.91]**	**[-1.65]**	**[-0.73]**	**[-2.45]**	**[-0.05]**	-
SECOND STAGE							
Dep. Variable	The prevalence of underweight	The prevalence of stunting	Energy_Supply_Adequacy	Protein_Supply	Depth_Food_Deficit	Anaemia_during_Pregnancy	Prevalence of under nutrition
Commercialization Index							**-9.314**
L1.							**[-0.990]**
Agricultural Openness							**-0.0061**
L1.							**[-1.527]**
Product Diversification							**4.503**
							[1.379]
log Agricultural Value Added per worker	**-0.073*** **	**-0.195*** **	**0.171*** **	**0.2671*** **	**-1.307** **	**-0.205** **	**-**
	[-3.057]	**[-4.695]**	**[4.249]**	**[3.068]**	**[-2.191]**	**[-2.422]**	
Control Variables	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**	**Yes**
Observations	373	367	515	414	447	439	389

R-squared	0.51	0.306	0.363	0.029	0.332	-0.225	0.330
Number of country	87	87	98	91	82	96	80
F test of excluded instruments	F(3, 279) =	F(3, 273) =	F(3, 410) =	F(3, 316) =	F(3, 358) =	F(3, 336) =	-
	16.24***	15.25***	8.18***	2.26*	2.73	1.93	
Prob > F =	0	0	0	0.0814	0.0438	0.1252	
Sargan statistic (over identification test of all instruments)	1.618	2.201	1.216	1.38	0.587	0.669	
Chi-sq(2) Pvalue	**0.4454**	**0.3328**	**0.5445**	**0.5016**	**0.7456**	**0.7156**	
Elasticity estimates	**Weight-for-Age**	**Height-for-Age**	**Energy_Supply_Adequacy**	**Protein_Supply**	**Depth_Food_Deficit**	**Anaemia_during_Pregnancy**	**Prevalence of under nutrition**
∂SDG2/∂log agrivapw	-0.073***	-0.195***	0.171***	0.267***	-1.307***	-0.205***	-
∂log agrivapw /Ag Openness	0.525***	0.504***	0.075***	0.046***	0.022***	0.047***	-
∂SDG2 /∂ Ag openness	**-0.038*** **	**-0.098*** **	**0.013*** **	**0.012*** **	**-0.029*** **	**-0.010*** **	**-0.006**

z-statistics in brackets. *** p<0.01, ** p<0.05, * p<0.1.

Table 7 SDG 10: Effects of Agricultural Transformation on Inequality

Dep. Variable	Gini	Rural Gini	Urban Gini	Growth Rate of Bottom 40%
Regions	All developing areas			
Data	Five-year average panel			
	Case 1	Case 2	Case 3	Case 4
EXP. VARIABLES		IV		OLS
FIRST STAGE				
Dep. Variable Commercialization Index				
L1.	-0.243	-0.272	-0.270	-
	[-0.79]	[-0.57]	[-0.56]	
Agricultural Openness				
L1.	**0.419*** **	**0.438*** **	**0.439*** **	
	[9.51]	**[5.25]**	**[5.21]**	
Product Diversification				
L1.	-0.051	0.152	0.152	
	[0.36]	[0.69]	[0.68]	
Control Variables	**Yes**	**Yes**	**Yes**	-
SECOND STAGE				
Dep. Variable	Gini	Rural Gini	Urban Gini	Growth Rate of Bottom 40%
log Agricultural Value Added per worker	**-0.066*** **	**-0.069***	-0.061	**-0.784***
	[-2.835]	**[-1.680]**	[-1.507]	**[-2.327]**
Control Variables	**Yes**	**Yes**	**Yes**	-
Observations	303	72	71	
R-squared	0.056	0.166	0.144	
Number of countries	91	22	22	
F test of excluded instruments	F(3, 204) = 30.52***	F(3, 43) = 9.67***	F(3, 42) = 9.51***	-
Prob > F =	0	1E-04	1E-04	
Sargan statistic (over identification test of all instruments)	2.841	3.275	1.652	
Chi-sq(2) Pvalue	0.242	0.194	0.438	
Elasticity Estimates	Gini	Rural Gini	Urban Gini	Growth Rate of Bottom 40%
∂Gini/∂log agrivapw	-0.066***	-0.069***	-0.061***	
∂log agrivapw /∂Ag Openness	0.419***	0.438***	0.439***	
∂Gini /∂Ag openness	**-0.028*** **	**-0.030*** **	**-0.027*** **	

Appendix 1: Details of Commercialisation Index

The commercialisation index is defined as:
[{Monetary value of production for aggregate crops processed (i.e. beer, cotton lint, cotton seed, margarine, molasses, oil (such as coconut oil, cottonseed oil, ground nut oil, linseed oil), palm kernels, sugar raw centrifugal, wine)} + {Monetary value of Production for Aggregate livestock processed (butter, cheese, milk, lard, yogurt)} + {Monetary value of production of green vegetables, fruits and derived products, and meat}]
/ [Monetary value of all the primary and processed crops and livestock]

The monetary value of production for aggregate crops processed is calculated by combining the data on production quantity on 'Crops processed' (http://www.fao.org/faostat/en/#data/QD) and 'Producer prices' (http://www.fao.org/faostat/en/#data/PP and (http://www.fao.org/faostat/en/#data/PA).[xxix] We also use the data on the value of agricultural production (http://www.fao.org/faostat/en/#data/QV) where the monetary values have been already derived from the price and quantity data files. The values are adjusted based on producer prices in the international US$ (PPP - Purchasing Power Parity) in 2004-2006.

This measure is based on the assumption that processed agricultural products are more likely to be commercialized. Below we provide the lists of processed/unprocessed crops and livestock.

Processed crops:
Margarine, short Sugar Raw Centrifugal Molasses Oil, soybean Oil, groundnut Oil, coconut (copra) Palm kernels Oil, palm Oil, palm kernel Oil, olive, virgin Oil, sunflower Oil, rapeseed Oil, safflower Oil, sesame Green vegetable tallow Oil, stillingia Cottonseed Oil, cottonseed Oil, linseed Beer of barley Wine Oil, maize Cotton lint

Primary crops:
Fruits and Green vegetables: Total Green vegetables Primary, dry Green vegetables & Melons, Total Fruit excl Melons, Cabbages and other brassicas Tomatoes Cauliflowers and broccoli Cucumbers and gherkins Onions, dry Garlic Peas, green Carrots and turnips Barley Green vegetables, fresh nes Apples Pears Quinces Apricots Cherries, sour Cherries Peaches and nectarines Plums and sloes Fruit, stone nes Berries nes, Fruit, tropical fresh nes Fruit, fresh nes

Non Fruits or Green vegetables: Cereals, nes Potatoes Wheat Sugar beet Cereals,Total Roots and Tubers,Total Pulses,Total Treenuts, Beans, Total Coarse Grain, Total Cereals (Rice Milled Eqv) Peas, dry Lentils Pulses, nes Walnuts, with shell Hazelnuts, with shell Maize Grapes Watermelons Figs Forage and silage, maize Forage products Green vegetables and roots fodder Rye Oats

Livestock processed:
Cheese of goat mlk Lard Silk raw Tallow Cheese (All Kinds) Skim Milk&Buttermilk,Dry Butter and Ghee Evaporat&Condensed Milk Cream fresh

Butter, cow milk Ghee, butteroil of cow milk Milk, skimmed cow Milk, whole condensed Whey, condensed Yoghurt Milk, whole evaporated Milk, skimmed condensed Milk, whole dried Milk, skimmed dried Milk, dry buttermilk Whey, dry Cheese, whole cow milk Cheese, skimmed cow milk Whey, cheese Butter, buffalo milk Ghee, of buffalo milk Cheese, buffalo milk Butter and ghee, sheep milk Cheese, sheep milk

Livestock primary:

Meat indigenous, sheep Meat, goat Milk, whole fresh goat Skins, goat, fresh Meat indigenous, goat Meat, pig Meat indigenous, pig Meat, chicken Eggs, hen, in shell Eggs, hen, in shell (number) Meat, duck Meat indigenous, duck Meat, goose and guinea fowl Meat indigenous, geese Meat, turkey Meat indigenous, bird nes Meat indigenous, turkey Meat, bird nes Eggs, other bird, in shell Eggs, other bird, in shell (number) Meat indigenous, chicken Meat, horse Meat, ass Meat, mule Meat indigenous, horse Meat indigenous, ass Meat indigenous, mule Meat, camel Milk, whole fresh camel Meat indigenous, camel Meat, rabbit Meat indigenous, rabbit Meat, game Meat, nes Offals, nes Snails, not sea Honey, natural Beeswax Silk-worm cocoons, reelable Meat indigenous, cattle and buffalo Meat indigenous, sheep and goat Meat, Total Meat indigenous, total Meat indigenous, poultry Milk,Total Eggs Primary Beef and Buffalo Meat Sheep and Goat Meat Meat, Poultry Meat, cattle

Appendix 2: A list of countries

Albania ; Algeria ; Angola ; Argentina ; Armenia ; Azerbaijan ; Bangladesh ; Belarus ; Belize ; Benin ; Bhutan ; Bolivia ; Botswana; Brazil ; Bulgaria ; Burkina Faso ; Burundi ; Cambodia ; Cameroon; Cape Verde ; Central African Republic ; Chad ; Chile ; China ; Colombia ; Comoros ; Congo, Dem. Rep. ; Congo, Rep. ; Costa Rica ; Cote d'Ivoire ; Croatia ; Czech Republic ; Djibouti ; Ecuador ; Egypt, Arab Rep. ; El Salvador ; Estonia ; Ethiopia ; Fiji; Gabon ; Gambia, The ; Georgia ; Ghana ; Guatemala ; Guinea ; Guinea-Bissau ; Guyana ; Haiti ; Honduras ; Hungary ; India ; Indonesia ; Iran, Islamic Rep. ; Iraq ; Jamaica ; Jordan ; Kazakhstan ; Kenya ; Kyrgyz Republic ; Lao PDR ; Latvia ; Lesotho ; Liberia ; Lithuania ; Madagascar ; Malawi ; Malaysia ; Mali ; Mauritania ; Mexico ; Micronesia, Fed. Sts. ; Moldova ; Montenegro ; Morocco ; Mozambique ; Namibia ; Nepal ; Nicaragua; Niger ; Nigeria ; Pakistan ; Panama ; Papua New Guinea ; Paraguay ; Peru ; Philippines ; Poland ; Romania ; Russian Federation ; Rwanda ; Sao Tome and Principe ; Senegal ; Serbia ; Seychelles ; Sierra Leone ; Slovak Republic ; Slovenia ; South Africa ; Sri Lanka ; St. Lucia ; Sudan ; Suriname ; Swaziland ; Syrian Arab Republic ; Tajikistan ; Tanzania ; Thailand ; Timor-Leste ; Togo ; Trinidad and Tobago ; Tunisia ; Turkmenistan ; Uganda ; Ukraine ; Uruguay ; Venezuela, RB ; Vietnam ; Yemen, Rep. ; Zambia

Appendix 3. Definitions and Descriptive Statistics of Variables

Five-year average data

Variable	Definition	N	Mean	SD	Min	Max
log Agricultural Value Added per worker	Agriculture value added per worker (constant 2010 US$)	776	7.58	1.2	4.94	12.43
Agricultural Value Added per worker	log of Agricultural Value Added per worker	776	4389.08	11875.94	140.17	2.50E+05
Commercialisation Index	Commercialization Index*1 (FAOSTAT)	1265	0.68	0.18	0.17	0.99
Agricultural Openness	[aggregate agricultural export] / [agricultural value added] (FAOSTAT)	831	0.36	0.82	0	13.17
Production diversity	Product diversification Index *2 (FAOSTAT)	1265	2.54	0.49	0.27	3.4
Non-Cereal_Share	**The share of non-cereal product production in total agricultural value added**	**1440**	**0.42**	**0.44**	**0**	**1**
Agricultural TFP Growth	Agricultural TFP Index (log) based on FAOSTAT (Fuglie, 2012 and 2015).	1229	0.01	0.02	-0.14	0.15
Land Area	Land area (sq. km)	1410	7.58E+05	1.92E+06	460	1.64E+07
Population Density	Population density (people per sq. km of Land Area area)	1404	75.49	105.33	0.78	1245.11
Fragility Index	State fragility index (= cspf_sfi)	446	11.22	5.88	0	23.8
	CPIA rating of macroeconomic management and coping with fragility (1=low to 6=high)					
Trade Openness	The share of exports and imports of goods in GDP.	1109	70.26	36.79	4.3	229.64
	The percentage of the working age population with an intermediate level of education	1428	0.73	0.42	0	1
Labour Force with Secondary Education	The percentage of the working age population with an intermediate level of education	1428	0.73	0.42	0.00	1.00
Urban Agglomerations	Population in urban agglomerations of more than 1 million (% of total population	894	17.1	11.08	1.19	49.97
Transport Equipment	Machinery and Transport Equipment (% of value added in manufacturing)	575	7.59	7.71	0	41.88
Tariff for primary goods	**Tariff rate, applied, weighted mean, primary products (%)**	556	8.75	8.01	0	55.48
Poverty headcount ($3.1 a day)	**Poverty headcount ratio at $3.10 a day (2011 PPP)**	**483**	**38.6**	**31**	**0**	**98.35**
Poverty headcount ($1.9 a day)	**Poverty headcount ratio at $1.90 a day (2011 PPP)**	**483**	**23.09**	**24**	**0**	**94.05**
Poverty headcount ($2 a day)	Poverty headcount ratio at $2.00 a day (2005 PPP)	433	38.94	31.34	0.01	98.1
Poverty headcount ($1.25 a day)	Poverty headcount ratio at $1.25 a day (2005 PPP)	433	22.05	24.44	0.01	90.3
Rural Poverty headcount ($2 a day)	Rural poverty headcount ratio at $2.00 a day (2005 PPP)	255	42.25	32.76	0	99.29
Rural Poverty headcount ($1.25 a day)	Rural poverty headcount ratio at $1.25 a day (2005 PPP)	255	25.33	26.01	0	97.53
Urban Poverty headcount ($2 a day)	Urban poverty headcount ratio at $2.00 a day (2005 PPP)	255	26.83	24.88	0	89.49
Urban Poverty headcount ($1.25 a day)	urban poverty headcount ratio at $1.25 a day (2005 PPP)	255	13.44	16.28	0	74.83
Child Malnutrition						
Weight-for-Age	**malnutrition prevalence, weight for age, (% of children under 5)**	**484**	**17.56**	**13**	**0.5**	**67.3**
Height-for-Age	**Prevalence of stunting, height for age (% of children under 5)**	**470**	**32.45**	**15.55**	**1.3**	**75.1**
Energy_Supply_Adequacy	**Average dietary energy supply adequacy (%) (3-year average)**	**624**	**113.01**	**14.05**	**70.75**	**151**
Protein_Supply	**Average protein supply (g/capita/day) (3-year average)**	**519**	**67.4**	**16.8**	**31**	**124**
Depth_Food_Deficit	**Depth of the food deficit (kcal/capita/day) (3-year average)**	**534**	**144.49**	**117.38**	**2**	**678.75**
Anaemia_during_Pregnancy	**Prevalence of anaemia among pregnant women (%)**	**570**	**40.17**	**12.12**	**19.7**	**68.78**
The Gini coefficient	**Gini coefficient for the national population (in raw value)**	646	40.82	9.18	19.4	74.33
Gini in rural areas	**Gini coefficient for rural areas (in raw value)**	91	32.64	5	23.85	48.47
Gini in uran areas	**Gini coefficient for urban areas (in raw value)**	88	35.78	5.46	24.6	51.38

Growth Rate of Bottom 40%	**The growth rate in the welfare aggregate of the bottom 40%**	58	2.83	3	-5.4	9.58
Asia	1 if in Asia 0 otherwise	480	0.53	1	0	1
LA	1 if in Latin America/ Caribbean or 0 otherwise	1428	0.19	0.4	0	1
SSA	1 if in Sub-Saharan Africa 0 otherwise	1428	0.37	0.48	0	1

Notes: *1. This is defined as: [{monetary value of production for aggregate crops processed (i.e. beer, cotton lint, cotton seed, margarine, molasses, oil (such as coconut oil, cottonseed oil, ground nut oil, linseed oil), palm kernels, sugar raw centrifugal, wine)} + {Monetary value of Production for Aggregate livestock processed (butter, cheese, milk, lard, yogurt)} + {Monetary value of production of green vegetables, fruits and derived products}] / [Monetary value of all the primary and processed crops and livestock]

*2. The index can be defined as $H' = -\sum_{i=1}^{R} p_i \ln p_i$ where R is the number of items of agricultural products and p_i is the share of production for item i, available from FAOSTAT.

*3. This is the growth in agricultural TFP indexes (based year 1992=100) over 1961-2012 using primarily FAO data, supplemented in some cases by national statistics. The output is FAO gross agricultural output (GAO) smoothed using the Hodrick-Prescott Filter (Lambda = 6.25). Input growth is the weighted-average growth in the quality-adjusted Land Area, labour, machinery power, livestock capital, synthetic NPK fertilizers, and animal feed, where weights are input (factor) cost shares. Agricultural TFP indexes are estimates by country and for groups of countries aggregated by geographic region and income class (Fuglie, 2012 and 2015).

Endnotes

[1] The literature suggests that access to remittances will improve productivity and reduce poverty only if they reach the poor and it is used for productive purposes (acquisition of land or machinery) (e.g. Chiodi et al. 2012; Baldé, 2011).

[2] The definition of processed agricultural products follows FAO (2011, 2014). Lists of processed and primary crops or livestock products are given in Appendix 1.

[3] We could construct the share of the input import in the input consumption, but the data on the fertilizer and pesticides import are available only after 2002 from FAOSTAT and unsuitable for the present purpose.

[4] We have plotted product diversification index and the share of non-cereal production in agricultural value added. As the country movers from the cereal production to non-cereal production, it sees an improvement in the agricultural productivity. Hence a positive correlation is expected. As expected, these variables are positively correlated with the coefficient of correlation 0.32, while the relationship between the two indices is not necessarily clear-cut. We can nevertheless confirm that as the country produces more non-cereal products the product diversification index tends to be higher. If we disaggregate it, the correlation for Asia is much higher (0.41) than for Latin America (0.07) or Sub-Saharan Africa (0.13).

[5] See http://www.fao.org/sustainable-development-goals/goals/goal-1/en/ for more details.

[6] See http://www.fao.org/sustainable-development-goals/goals/goal-2/en/ for more details.

[7] It is noted that FAO measures rely mainly on *calorie availability*, rather than *calorie intakes*. The measures are based on the means and variances for a limited number of countries with detailed micro-data available and a skew normal distribution to determine the proportion of undernourished. However, for the cross-country analyses, this is the best

dataset for food security in terms of coverage of the countries and thus we have decided to use the FAO measures. See IFAD, WFP, and FAO (2012) for details of FAO measures on food security.

[8] Its discussion paper version was released in 2013.

[9] There is a limitation in the data of agricultural TFP (Alston and Pardey, 2014) to be discussed later.

[10] This is supported by the maximum variance inflation factor of 1.76 (less than 10, the threshold commonly used in the literature) in the static case.

[11] The results will be provided on request.

[12] We used the estimations based on unbalanced data as our preferred cases because the use of balanced data will eliminate 26 countries from the sample, which has a substantial share in our sample.

[13] We have also applied the Fixed-Effects IV model by instrumenting AT by external instruments, namely, urban agglomerations (population in urban agglomerations of more than 1 million (% of total population)), transport equipment machinery (% of value added in manufacturing), and tariff for primary goods. The results are broadly consistent with those based on a system GMM.

[14] Ideally, both directions of causality from $\boldsymbol{AT}_{it}$ to $\boldsymbol{AG_{it}}$, and from $\boldsymbol{AG_{it}}$ to $\Delta\boldsymbol{AT}_{it}$ should be explicitly considered in the model. However, we consider mainly the former (by treating $\boldsymbol{AT}_{it}$ and its lags endogenous in a system GMM).

[15] The inclusion the lags up to the second period is guided by statistical significance of the third lag as well as specification tests, such as serial correlation tests, AR(1) and AR(2). An inclusion of the third lag, however, does not change the results significantly, although the number of observations reduces.

[16] Two issues have to be resolved in estimating the dynamic panel model. One is endogeneity of the regressors and the second is the correlation between $(AG_{it-1} - AG_{it-2})$ and $(\varepsilon_{it-}\varepsilon_{it-1})$ (e.g. see Baltagi, 2005, Chapter 8). Assuming that ε_{it} is not serially correlated and that the regressors in $\boldsymbol{X}_{it}$ are weakly exogenous, the generalized method-of-moments (GMM) first difference estimator (e.g. Arellano and Bond, 1991) can be used.

[17] See Roodman (2009) for more details of System GMM and practical guides.

[18] It is noted that poverty or inequality panel data have more missing variables than the data on agricultural productivity.

[19] We have estimated the same models using the annual panel data and have obtained broadly similar results.

[20] On the results of System GMM in Cases 5-8 in Table 2 are broadly justified by the specification tests as AR(1) is significant and AR(2) is not at the 5% level, while both Sargan and Hansen tests are not statistically significant at the 5% level. The case with the initial level of log agricultural value added per worker (Case 6) is weak as the test statistics are significant at the 10% level for both Sargan and Hansen tests. As the Hansen test is deemed more robust than the Sargan test, we will mainly adopt the former in evaluating the performance of the dynamic model.

[21] It is not straightforward to choose whether unbalanced or balanced data are used and this should be judged with respect to the study objective and the pattern for missing observations (Baltagi and Song, 2006) as making the data balanced may worsen the performance of the estimators when compared to those from the entire unbalanced data (Baltagi and Chang, 1994). We have decided to use unbalanced data as covering more countries is crucial for the main objective of our study.

[22] The results will be provided on request.

[23] We have also examined the effects of agricultural transformation on agricultural TFP growth based on Fuglie (2012, 2015). Contrary to the expectation, agricultural transformation indices do not have any positive effect on agricultural TFP growth. Given that Fuglie compared the changes in output and unit costs in constructing the agricultural TFP growth, they are supposed to be more accurate proxies of agricultural productivity. However, the question is how Fuglie's TFP measure reflects the actual productivity. When we plot log agricultural value added per worker and the agricultural TFP growth, there is a positive association in the positive range of TFP growth, while there is a negative relation in its negative range. A similar relationship is found in the relationship between log agricultural value added per worker and the agricultural TFP index. It is implied that there might have been an overvaluation in some (imputed) input values (e.g. machinery) in the agricultural TFP index. Alston and Pardey (2014) have questioned the validity of the Fuglie's (2012) measure of agricultural TFP. If we drop negative values in the agricultural TFP growth, for instance, the results are similar to those for log agricultural value added per worker and its growth where the agricultural openness has a positive and significant coefficient estimate. Details will be provided on request. Given the potential problem in agricultural TFP growth measures, this paper focuses on agricultural value added per worker as a broad measure of productivity.

[24] While AR(2) is not significant in Cases 1-3, AR(1) is not significant either and so the results should be interpreted with caution.

[25] We have carried out the same regressions for the balanced panel for the cases where a dependent variable is log agricultural value added per capita. The results are broadly similar to those in Table 4. However, our results will of course never underestimate the role of horticultural exports, the growth in urban demand for animal products and other high value foods in Africa, which may not be fully captured by our model.

[26] The results based on annual panel data are very similar and consistent. Regressions based on the balanced panel will produce similar results for some indicators, such as poverty, child malnutrition and the Gini coefficient. These will be provided on request.

[27] The results will be provided on request.

[28] It is noted that regional regressions in Table 4 show negative coefficient estimates of product diversification for Asia and Sub-Saharan Africa.

[xxix] However, a limitation of the index is that prices have missing observations and thus cannot be fully matched with the crop quantity data.