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Supporting agriculture in developing countries: new insights on the impact of official development assistance using a climate perspective

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Abstract

Agriculture is a major source of food and income for poor and rural households living in developing countries; yet, agricultural systems are increasingly threatened by changing climate conditions that compromise their productivity and resilience. Over time, international aid has provided support to the agricultural systems of recipient countries, though the literature is not unanimous in confirming their effectiveness.

To shed light on this issue, the purpose of this work is to assess the efficacy of these aid in increasing the agricultural productivity of recipient nations, employing original approaches.

First, to adopt a climate change perspective, we conduct our analysis using a recent classification adopted by the Official Development Assistance—the Rio Markers—which distinguishes aid between adaptation and mitigation to climate change.

Second, taking into account that the starting conditions of recipient countries can significantly impact aid effectiveness, we classify 115 developing countries into four subgroups according to their vulnerability and readiness to climate change, as evaluated by the ND-Gain indicators.

We perform a two-stage instrumental variable approach within the context of panel models to investigate the potential growth-enhancing impact that different types of agricultural aid may exert on the agriculture Total Factor Productivity in recipient countries.

Our findings show that aid to agriculture, especially adaptation aid, has a positive impact on agricultural productivity growth. We also observe that countries with a higher climate readiness benefit the most from aid, whereas countries highly vulnerable and heavily dependent on the agricultural sector are less able to leverage the aid received to the same extent.

Overall, our analysis confirms the importance of international aid to the agricultural sector and suggests that accurate impact assessment analyses should also consider a climate perspective to distinguish adaptation from mitigation aid.

Keywords: Official development assistance, Total factor productivity, Developing countries, Rio climate markers, ND-GAIN, Climate adaptation

Introduction

In developing countries, the livelihood of rural and poor households largely depends on agriculture, which provides them with food, income, and employment. In some of these countries, agriculture even accounts for up to 70% of total employment, and its contribution to the overall GDP is often even higher (International Labour Organization 2021). Also, in the least developed countries, agriculture can be the engine of growth (Ravallion and Datt 1996), also adding up to growth in other sectors (Tiffin and Irz 2006; Kaya et al. 2013), and can thus have a deep effect at reducing poverty (Irz et al. 2001; Christiaensen and Martin 2018).

Agriculture also provides critical inputs to other non-agricultural economic sectors, such as industry and services, and is a significant source of foreign exchange through exports of agricultural products (World Bank 2007; Christiaensen et al. 2011). Moreover, by providing food at reasonable prices in urban areas, agriculture can help improve food security for urban populations (Dethier and Effenberger 2012).

However, the impact of agriculture on economic growth in developing countries is complex and depends on various factors. In many developing countries, rural communities are often marginalized and suffer from a lack of basic services, making rural development a crucial aspect of overall development efforts. Furthermore, these countries are often constrained by a variety of factors, such as lack of access to technology, inputs, and markets. In addition, climate change, with the increased frequency and intensity of extreme weather events, changes in precipitation patterns, and rising temperatures (Mbow et al. 2017) is expected to have a significant impact on agricultural production especially for developing countries (Mendelsohn 2009; Chen et al. 2016; Zaveri et al. 2020). The expected reduction in agricultural productivity resulting from climate change coupled with farmers' increased difficulty adapting to changing conditions (Thornton et al. 2018) could have a significant impact on overall economic growth and food security (Mbow et al. 2017; FAO, IFAD, UNICEF, WFP and WHO 2020).

To moderate the adverse impact of changing climate conditions, farmers' resilience must be strengthened and supported: for this purpose, international aid can provide the funding and resources needed for programs and initiatives that can help farmers increase their adaptive capacity. This international assistance can include investment in infrastructures (roads, water systems, storage facilities), and training in sustainable agricultural practices (such as conservation agriculture, agroforestry, and integrated pest management) (FAO 2018). In addition, granting farmers access to innovative cultivation systems and technologies that are more resistant to extreme weather conditions can help improve agricultural productivity and reduce the risk of crop failure (Fisher et al. 2015; Makate et al. 2019; Tóth et al. 2020; Adzawla and Alhassan 2021). Enhanced agricultural productivity and improved resilience could in turn improve farmers' living standards and confirm the effect on overall economic growth and poverty reduction that has been observed in the past (Ravallion and Datt 1996; Kaya et al. 2013).

One of the most relevant forms of international assistance is the flow of economic resources from the official sectors of countries belonging to the OECD Development

Assistance Committee (DAC). This flow of economic resources, also known as Official Development Assistance (ODA), promotes economic growth and social welfare in least developed countries at concessional terms and can play a critical role in strengthening the resilience of developing countries, particularly in the face of the challenges posed by climate change. Since their introduction, ODA has increased over time; yet, the amount of aid directed to the agricultural sector has decreased even though this sector was a major recipient of aid in the past. Moreover, despite the positive intent behind international aid, studies on their effectiveness have yielded contrasting results. Indeed, alongside positive impacts, these aids have also given rise to adverse effects in recipient countries.

In light of these considerations, the focus of this paper is on that component of ODA specifically directed to agriculture, with the aim of assessing whether and where it contributes to increasing the level of agriculture productivity and, consequently, to help contrast climate change and to reduce the level of poverty and thus food insecurity.

Compared to current studies, we contribute to the literature on the effectiveness of international aid through a climate change perspective using original approaches. First, we estimate the impact of agricultural aid using a recent classification used by the Rio Markers (OECD 2016), which distinguishes aid between adaptation and mitigation to climate change. To the best of our knowledge, this classification system has not been yet used to evaluate the effectiveness of ODA in fostering the agricultural productivity of recipient countries. Provided that the effectiveness of agricultural aid is often questioned, we exploit this recent classification system to provide a more accurate assessment of agricultural aid.

Second, we assess the effectiveness of agricultural aid in 4 subsamples of countries identified by their vulnerability and readiness to climate change using the Notre Dame Global Adaptation Initiative (ND-GAIN) composite indexes (Chen et al. 2015) that combine multiple indicators into scores reflecting a country's overall level of climate characteristics. The literature has shown that aid effectiveness depends largely on the conditions in which the recipient country is, but no work has related aid to country characteristics related to climate change.

This article is structured as follows: Sect. "Literature review" discusses the related literature on international aid; Sect. "Data and methods" presents the data used in the analysis and the empirical methods; Sect. "Econometric results" presents the results that are discussed in Sect. Discussion and Sect. "Concluding remarks" concludes.

Literature review

Ever since its beginning, ODA gained considerable attention in the academic debate. The effectiveness of ODA in general has been explored with regard to different issues: economic growth, civil conflicts, food security, agricultural productivity, and characteristics of aid-receiving countries. Nonetheless, despite the widespread debate on the role of ODA as a promoter of economic growth and social welfare in recipient countries, a clear consensus is still missing, as the evidence regarding their actual effectiveness is often contrasting.

A comforting evidence of the effectiveness of ODA can be found in Burnside & Dollar (2000), who found a positive effect of foreign aid on growth only in those recipient countries with good fiscal, monetary, and trade policies. This aid-growth nexus has been later confirmed in the literature review of Arndt et al. (2010), at least in the long run. The recent quasi-experimental approach of Galiani et al. (2017) found further proof of the positive effect that foreign aid can have on economic performance: in their analysis, a 1 percentage point increase in aid received raises per capita growth by 0.35 percentage points. As for the impact on the incidence of conflicts, the work of Mary & Mishra (2020) stated that a 10 percent increase in total humanitarian food aid reduces the frequency of civil conflicts by 0.2 percent; a similar negative effect is observed on the duration of conflicts.

The ability of ODA to promote food security and agricultural productivity was first identified in the seminal work of Norton et al. (1992), where it is found that foreign assistance from 1970 has improved agriculture in Asia and, to a lesser extent, in sub-Saharan Africa but not in the Middle East or Latin America. Still, a study by Alabi (2014) investigated the impact of foreign agricultural aid on agricultural GDP and productivity in Sub-Saharan Africa (SSA) concluding that these aid had a positive impact more when are bilateral rather than multilateral. Work by Ssozi et al. (2019), Barkat & Alsamara (2019) and Kornher et al. (2021) also found positive relationships between aid and growth in agriculture. A positive growth-enhancer effect has been observed also in Kaya et al. (2013), where foreign aid to agriculture reduces both directly and indirectly the poverty headcount ratio of recipient countries, a result that confirms the poorest welfare-enhancing effect of aid to agriculture. Recently, a positive nexus between agricultural ODA and Foreign Direct Investments in the agri-food industry of recipient countries has also been uncovered (Tian 2023).

In terms of promoting economic growth in recipient countries, the existence of an aid-growth nexus has been instead contested by other authors (Rajan and Subramanian 2008). Similarly, the instrumental variable approach by Dreher & Langlotz (2020), based on donors' country fractionalization, found a positive though insignificant role of foreign aid on recipient per capita income growth. ODA, and humanitarian aid in particular, has been also blamed for increasing the frequency and duration of intra-state civil conflicts in recipient countries (Nunn and Qian 2014). The ability of aid to contrast food security has been equally criticized (Petrikova 2015). For instance, in Mary et al. (2020), agricultural aid only have a limited impact on reducing child stunting: a 10% increase in agricultural aid only reduces child stunting by 0.5%. Last but not least, the lower than expected returns from aid to agriculture might explain the sharp reduction in aid to the primary sector that took place over time (Mattoo et al. 2020) as displayed in Fig. 1.

A critical point in the study of the use of ODA, which could pave the way for new strands of studies, concerns the type of classification used to categorize these aids. In 2010, the OECD introduced an ODA classification system using Rio markers encompassing aspects related to climate change. In particular, these markers distinguish mitigation interventions, aimed at minimizing the impact of human activity on polluting emissions, from adaptation ones, that provide individuals with the tools to cope directly with the effects of climate change and natural hazards (OECD 2016).

As of today, studies employing the mitigation-adaptation classification only investigate the characteristics of recipient countries, rather than delving into the assessment of aid effectiveness. Halimanjaya (2015) for instance observed that recipient countries

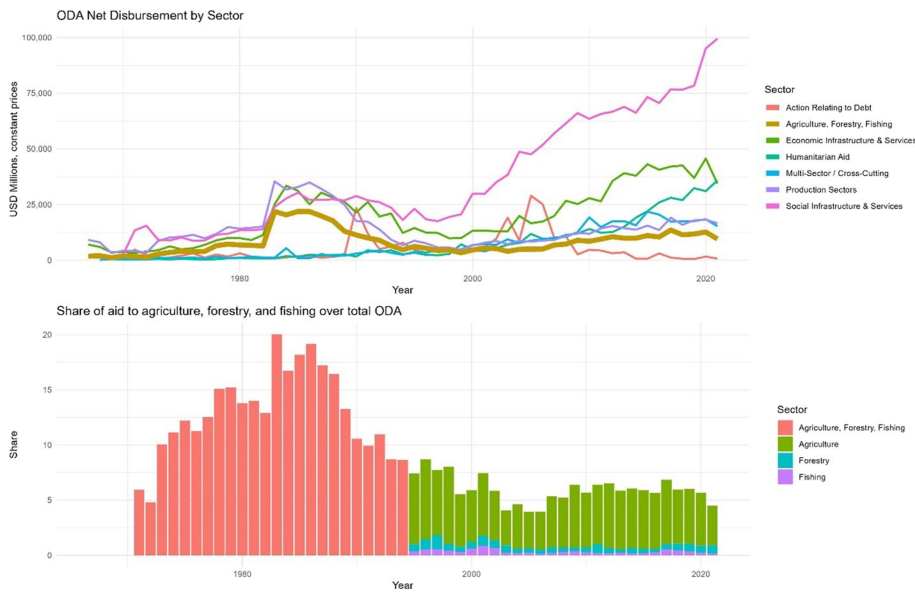

Fig. 1 Official Development Assistance (ODA) sectoral allocation from the 1970s *Source: authors' elaboration using OECD statistics*

with a high CO2 intensity, large carbon sinks, and good governance receive mitigation aid, whereas adaptation aid are allocated to countries with lower CO2 emission intensities. Weiler et al. (2018) used this classification method to identify the donors' underlying motive for allocating adaptation aid to recipient countries. Their analysis indicated that recipient countries' governance quality is an aid attractor; yet, perhaps more importantly, donors seem to privilege countries that could become trade or business partners. More recently, Iacobuță et al. (2022) observed that the gap between mitigation and adaptation aid is shrinking, since donors, considering adaptation as a public good, are re-evaluating the importance of adaptation assistance. With the growing importance of the climate perspective in gauging the efficacy of global aid efforts, our study addresses specifically this literature gap by quantifying the growth in agricultural productivity within developing countries resulting from both adaptation-oriented and mitigation-oriented aid.

Another strand of research has attempted to investigate the effectiveness of ODA based on the attributes of beneficiary nations. In this case, the literature has shown that aid effectiveness depends largely on the conditions in which the recipient country is (Hudson & Mosley 2001; Mosley et al. 2004; Dalgaard et al. 2004; Maruta et al. 2020); among these, institutional quality is one of the most relevant determinants for a good project outcome (Baliamoune-Lutz & Mavrotas 2009; Denizer et al. 2013) and is relevant for enhancing agricultural productivity, too (Lio & Liu 2008; Lio & Hu 2009). Nevertheless, as far as we are aware, there has been no research conducted on the impact of aid on agricultural productivity while considering the specific traits of the aid-receiving countries concerning their responsiveness to climate change.

A highly appealing method for categorizing countries within the context of climate change is offered by the Notre Dame Global Adaptation Initiative (ND-GAIN). This initiative offers two indicators that pertain to the country's current vulnerability to climate disruptions and the country's readiness to leverage private and public sector investment for adaptive actions. These indicators have been extensively employed in the literature primarily to establish a relationship between the characteristics of countries and the aid they have received. For instance, Robertsen et al. (2015) highlight that the countries in Africa most vulnerable to climate impacts are not necessarily the ones receiving the highest amount of aid. Delving further into this matter, the study by Jain and Bardhan (2023) investigates the connections between ODA disbursements and climate vulnerability. Additionally, it examines the intermediary function of adaptation readiness within 119 developing nations, thereby suggesting a lack of adaptation mainstreaming into ODA disbursement with respect to vulnerability and readiness. The same conclusion is arrived at by Savvidou et al. (2021), who emphasize the inadequacy of aid in countries that are most susceptible and least responsive to the impacts of climate change.

In our study, we go beyond the analysis of the distribution of aid based on country characteristics related to climate change. Instead, we advance the literature by employing ND-GAIN indexes to investigate whether the climate vulnerability and readiness of recipient countries significantly influence adaptation aid effectiveness, particularly in the context of agricultural productivity—an aspect that, to the best of our knowledge, has not been previously explored in the literature.

Data and methods

Data

Regarding international aid data, the Official Development Assistance (ODA) collected by the OECD-Development Assistance Committee (DAC) was taken into consideration. The flow of ODAs started in the 1960s (Hynes and Scott 2013) and currently targets different areas of intervention, such as humanitarian assistance, food aid, social infrastructures and services, and agriculture. As can be observed from Fig. 1, total aid has increased over time; yet, agriculture, which was one of the major recipient sectors in the past, has been gradually allocated with a declining amount of aid over time. The agricultural sector was in fact a major recipient of assistance in the 1970s and 1980s (Cabral and Howell 2012) but the contributions received gradually declined over time and now account for only 5% of total contributions. Social infrastructure and services is now the largest recipient sector.

In 1998, the OECD-DAC introduced a first classification system (Rio markers) to group ODA into these three categories: biodiversity, climate change mitigation, and desertification. In 2010, a fourth marker dedicated to climate change adaptation aid was introduced. The Rio markers for climate change now distinguish mitigation interventions, aimed at minimizing the impact of human activity on polluting emissions, from adaptation ones, that provide individuals with the tools to cope directly with the effects of climate change and natural hazards (OECD 2016). Adaptation and mitigation aids are further classified into principal or significant. An activity is principal when "the objective is explicitly stated as fundamental in the design of, or the motivation for, the activity"; it is classified as significant whenever the "objective is explicitly stated but it is not the fundamental driver or motivation for undertaking it" (OECD 2016).

To evaluate the effectiveness of ODA at stimulating agricultural productivity growth, this analysis considers a sample of 115 countries (see Table 5 in Appendix) that have received ODA in terms of "principal" adaptation or mitigation aids dedicated to "agriculture". We collected annual data from 2010 to 2020, obtaining 1170 observations. The data are publicly available in the Creditor Reporting System Database and are in 2020 USD. Our definition of agricultural aid slightly departs from that of Kornher et al., (2021) as it excludes food aid and aid targeting environmental protection from the definition of agricultural aid; we include instead aid targeting water supply and sanitation, which can respectively improve irrigating systems, and thus agricultural productivity, and living standards and food storage of rural households.

Our variable of interest is agricultural Total Factor Productivity (TFP) estimated and collected by USDA, which is defined as the amount of agricultural output produced from the combined set of land, labour, capital, and material resources employed in farm production. If total output is growing faster than total inputs, then the total factor productivity is increasing.

In this paper, we have chosen to focus on an aggregate measure of agricultural productivity, without delving into the differentiation of various input factors, in order to accommodate the concept of substitutability among them. Total Factor Productivity (TFP) has been specifically formulated to address the constraints and biases associated with the application of partial productivity measures, as elucidated by seminal literature (Christensen 1975), and it is recommended for cross-country comparative analyses (Shumway et al. 2016). Each TFP data series is an index with a base year of 2015, such that the value of TFP for each country or region is set to 100 in 2015. Thus, the value of the index in any year is the level of TFP relative to 2015. An international comparison of TFP in different countries does not indicate where productivity levels are higher or lower, but rather where agricultural productivity has grown faster over time.

The classification of countries according to a climate perspective was carried out by the Country Index of the Notre Dame Global Adaptation Initiative (ND-GAIN), a freely accessible index that displays a country's existing vulnerability to climate-related disturbances. Moreover, it evaluates a nation's readiness to utilize investments from both the private and public sectors for adaptive actions. The ND-GAIN Country Index compiles over 40 core indicators of 182 United Nations member countries from 1995 to the present.

To analyze the effect of aid in relation to the characteristics of recipient countries, we then divide our sample into 4 groups according to indicators that express the country's current vulnerability to climate disruptions and its readiness to leverage private and public sector investment. Both vulnerability and readiness indexes combine multiple indicators into a single score to reflect a country's overall level of climate readiness and vulnerability. Specifically, vulnerability expresses "*The propensity or predisposition of human societies to be negatively impacted by climate hazards*"; Chen et al. 2015) and is based on three components: the *exposure* of the economic sectors to climate-related or climate-exacerbated hazards; the *sensitivity* of to the impacts of the hazard and the *adaptive capacity* to cope or adapt to these impacts. Readiness means a country's ability to "*Make effective use of investments for adaptation actions thanks to a safe and efficient business environment*" (Chen et al. 2015). It comprises other three components: economic, governance, and social. While *economic readiness* apprehends the national business environment based on which adaptation reduces sensitivity and improves adaptive

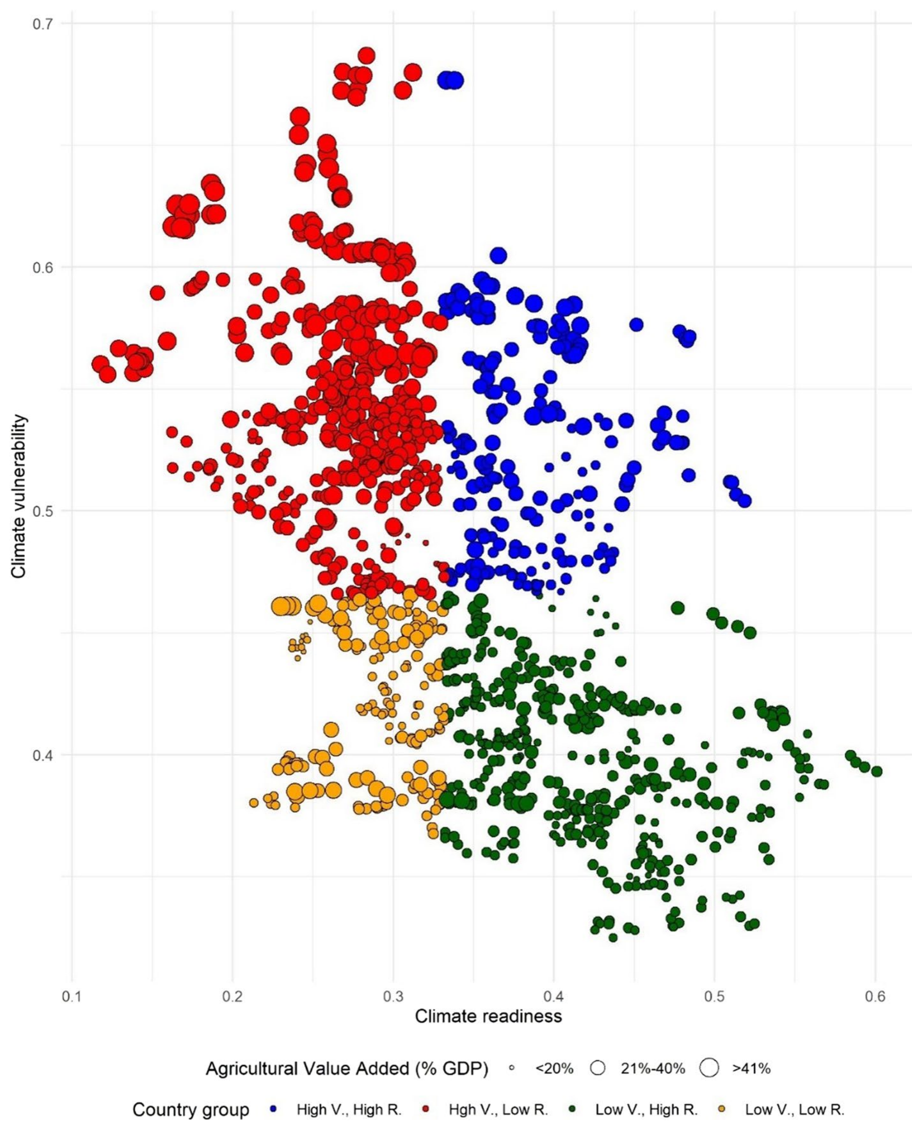

Fig. 2 Countries climate vulnerability and readiness indexes weighted by the Agricultural Value Added (% of GDP) *Source: Authors' elaborations to re-adapt the climate matrix data of* Chen et al. (2015) *to the sample data used in the analysis. The Agricultural Value Added as a share of GDP is retrieved from the World Bank and refers to the Value Added of Agriculture, Forestry, and Fishing. The cut-offs used to sort countries into high or low climate vulnerability or readiness are the sample median values*

capacity, *governance readiness* focuses on institutional strength to ensure proper investment. *Social readiness* deals with social inequality, education, information systems, and innovation that affect investment and promote adaptation actions.

By applying the ND-GAIN climate indicators to our sample of recipient countries, we can distinguish four different combinations of climate vulnerability and readiness, which are displayed in Fig. 2 below (see Table 6 in the appendix for the detailed list). Each point is a combination of vulnerability and readiness levels, weighted by the ratio between agricultural value added and GDP: the greater this ratio, the greater the size of the point in Fig. 2. In the left top panel, there are those countries with high vulnerability and low readiness. Countries in the bottom right of the matrix have low values of vulnerability and high values of readiness; the top right panel identifies countries with high vulnerability but also high levels of readiness. Last, countries in the bottom left have low levels of vulnerability and low levels of readiness.

Figure 2 also shows the country's dependence on the agricultural sector. Interestingly, the countries that depend mainly on agriculture activity (larger points) are also the most vulnerable and have the lowest readiness. Conversely, countries, where agriculture has a lower impact on economic activity (smaller points), are the least vulnerable and the most able to adapt to climate change and its potential to improve its adaptive capacity in the future.

We also consider some control variables previously used in the literature in the assessment of foreign aid effectiveness (Burnside and Dollar 2000; Dreher et al. 2021) that could compromise or reinforce the effectiveness of foreign aid. These are the ratio between broad money and GDP, the Food Consumer Price Index, weather variables (temperatures and precipitations), political stability, received personal remittances, and trade openness. All these variables are in fact able to influence agricultural productivity as explained below.

A positive relation between money supply and agricultural productivity has been observed in the literature (Kargbo 2007; Gil et al. 2009). The ratio between broad money and GDP can in fact proxy money supply and thus monetary policy. Expansionary monetary policies reduce the interest rate and thus the cost of investments, favouring in turn capital accumulation also in the primary sector.

Food prices are linked to agricultural productivity. Higher food prices can encourage farmers to increase their market involvement and invest in agricultural technologies (Benfica et al. 2017). However, high prices in certain cases can reduce investment capacities and exacerbate food insecurity, especially in low-income countries reliant on agriculture that can barely react to international shock prices (Pingali 2007a; Ivanic and Martin 2008; Warr 2014). For instance, during the 2008 food price crisis, many developing countries were unable to respond effectively to changing agricultural prices (Wodon and Zaman 2010).

The role of weather conditions in influencing agricultural output has been well documented in the literature, both in developed and developing countries, where adverse weather shocks reduce agricultural productivity (Grace et al. 2015; Chavas et al. 2019).

Political stability, which is also a proxy for institutional quality, improves a country's ability to attract foreign investments and development assistance (Burnside and Dollar 2000; Weiler et al. 2018). Better governance can also boost agricultural productivity by favouring the accumulation of agricultural capital (Lio and Liu 2008; Lio and Hu 2009).

Remittances can have a profound positive or negative effect on agricultural productivity: they can compensate for the reduction in agricultural labour supply and reduce liquidity constraints (Rozelle et al. 1999; Taylor et al. 2003; Wonyra and Ametoglo 2020), but they can also reduce working incentives and thus labour productivity by increasing the reservation wage (Amuedo-Dorantes and Pozo 2006). To avoid a confounding interpretation of the effectiveness of aid on agricultural productivity, remittances are thus included in both robustness specifications.

Table 1 Descriptive statistics of the variables used in the model for the sample period 2010–2020

Variable	Obs	Mean	Std. Dev	Min	Max
Total agricultural aid (*adaptation and mitigation, financial value, 2020 USD '000; OECD*)	1170	13478.36	34419.45	0.00	369664.60
Adaptation agricultural aid (*financial value, 2020 USD '000; OECD*)	1170	10315.39	26980.82	0.00	270324.10
Mitigation agricultural aid (*financial value, 2020 USD '000; OECD*)	1170	3162.97	20,488.43	0.00	361519.30
Total agricultural aid (*adaptation and mitigation, number of projects; OECD*)	1170	4.47	9.10	0.00	203.00
Adaptation agricultural aid (*number of projects; OECD*)	1170	3.41	8.56	0.00	203.00
Mitigation agricultural aid (*number of projects; OECD*)	1,170	1.06	1.98	0.00	19.00
Total agricultural aid (*adaptation and mitigation, average financial value, 2020 USD '000; OECD*)	1170	4.83	3.38	0.00	12.01
Adaptation agricultural aid (*average financial value, 2020 USD '000; OECD*)	1170	4.20	3.55	0.00	11.81
Mitigation agricultural aid (*average financial value, 2020 USD '000; OECD*)	1170	2.49	3.21	0.00	12.10
Agricultural TFP (*base year 2015 = 100; USDA*)	1170	100.97	11.08	64.34	163.49
Total readiness (*from lowest, 0, to highest, 1; ND-GAIN*)	847	0.34	0.08	0.16	0.57
Total vulnerability (*from lowest, 0, to highest, 1; ND-GAIN*)	847	0.47	0.08	0.32	0.69
Broad money (*Share of GDP; World Bank*)	914	50.35	32.15	9.02	260.62
Food Consumer Price Index (*base year 2015 = 100; FAOSTAT*)	943	110.97	130.28	8.57	3644.44
Average temperatures (*C°; World Bank*)	943	21.78	6.22	0.04	29.30
Average precipitations (*mm; World Bank*)	852	100.01	69.12	1.93	373.84
Political stability and absence of violence/terrorism index (*from lowest, -2.5, to highest, + 2.5; World Bank*)	852	− 0.52	0.79	− 2.81	1.20
Remittances (*Share of GDP; World Bank*)	943	5.69	6.40	0.00	43.77
Trade openness (*Share of GDP; World Bank*)	932	73.22	33.54	0.78	320.94

Trade openness and increased exports could sustain agricultural development in different ways: countries with a comparative advantage in agriculture, just like most ODA recipients are, become exposed to international competition, and could greatly benefit from having access to foreign markets; also, domestic consumers would have access to an enriched gamma of food products and their diversified preferences would favour the nutrition transition (Pingali 2007b). Even though trade openness seems to support agricultural productivity growth (Hassine and Kandil 2009; Gáfaro and Pellegrina 2022), most vulnerable countries, such as Sub-Saharan Africa countries, are characterized by very uncompetitive and unproductive agricultural systems (Pingali 2007b). In this sense, higher trade flows might increase food imports and thus compromise agricultural development. In terms of food security, trade might compensate for insufficient domestic production (Porkka et al. 2013), at the cost of increasing countries' exposure to shocks in foreign prices, though remittances and foreign aid might offset such effect (Combes et al. 2014).

The descriptive statistics of all variables for the sample period 2010–2020 are reported in Table 1.

Econometric specification: an instrumental variable approach

Empirical analysis that examines the effectiveness of foreign aid or ODA on certain outcomes, such as agricultural productivity, must deal with a significant level of endogeneity. A source of endogeneity is reverse causation, by which ODA is allocated to countries with particularly low levels of agricultural productivity. In this case, standard OLS estimates are biased and do not capture the actual effect of aid on agricultural productivity.

In order to deal with this potential source of endogeneity, we perform a two-stage least square (2SLS) instrumental variable approach. In such a setting, for the first stage, the chosen instrument has to be related to the instrumented variable but not to the dependent variable. In other words, a suitable instrument is related to ODA but not to agricultural productivity in recipient countries.

In particular, to identify the instrumental variable we consider the interaction between a time-series variable and a cross-section indicator following Nunn and Quian (2014) approach.

The time-series variable used is the Federal Reserve USA Industrial Production Index, that can proxy global real economic activity and can consequently influence the amount of assistance provided by donor countries (recalling that OECD donor countries are asked to allocate up to 0.7% of the Gross National Income to ODA). The cross-sectional dimension in our case is the recipient country's probability of receiving assistance, computed as the ratio between the number of years in which foreign aid have been received over the total number of years included in the sample. Thus, the instrument now varies by country and time period, which allows us to control for year fixed effects. We allow the time effects to differ across countries and control for countries and year fixed effects.

Provided that the instrument cannot be correlated with the error term of the explanatory equation, conditionally on the other covariates, the exclusion restriction (i.e., the instrument affects productivity only through aid) would be violated as long as the probability of receiving agricultural assistance influences agricultural productivity; yet, in our analysis, we control for country and year fixed effects to make sure that the instrument is an exogenous variable with no effect on agricultural productivity other than the effect it has on ODA. Provided that our econometric approach resembles a Diff-in-Diff approach (Nunn and Qian 2014; Dreher and Langlotz 2020; Dreher et al. 2021), our identifying assumption thus states that agricultural productivity in countries with different probabilities of receiving aid is not affected differently by changes to the industrial production index other via the impact of agricultural aid whilst controlling for country and year fixed effects.

To visually test this, we inspect the trends in the Industrial Production Index as well as the trends in agricultural productivity and aid received (Christian and Barrett 2017) among "Regular" and "Irregular" recipient countries, i.e., countries that have received respectively more or less aid than the sample median probability of receiving aid. Such trends are displayed in Fig. 3.

Following Christian and Barrett (2017), from the visual inspection of the trends pictured in Fig. 3 we have little reason to believe that the parallel trends assumption is violated. The trends in aid received and the trends in agricultural productivity are in fact largely parallel across the two groups.

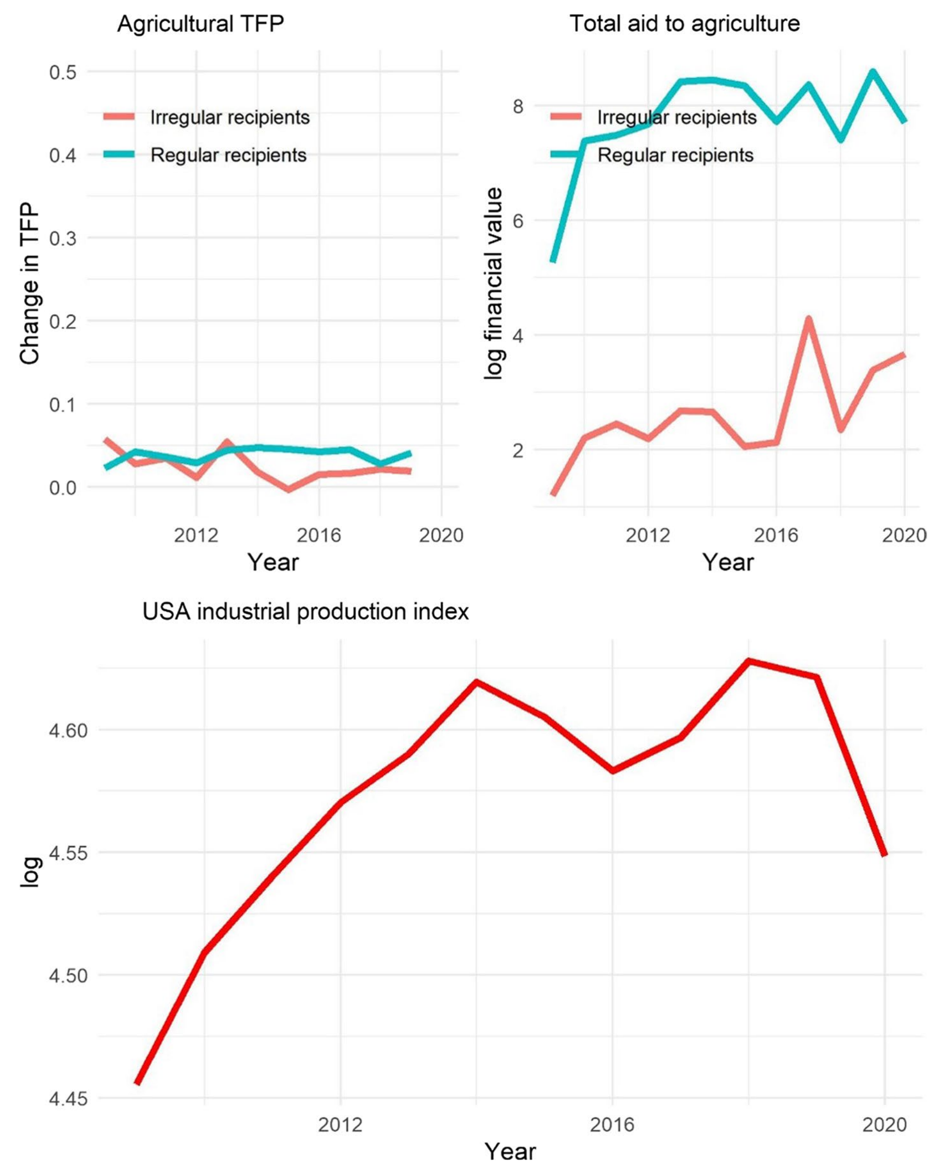

Fig. 3 Trends in aid received and in agricultural productivity changes in Regular and Irregular recipient countries Source: authors' elaboration on OECD data (total agricultural ODA received), USDA data (agricultural TFP), Federal Reserve Economic Data (for the US industrial production index). Note: Regular and Irregular recipient countries are defined with respect to the sample median probability of receiving total agricultural aid

In light of these results, we can formulate our empirical specification by introducing the two regression equations below:

$$y_{it} = \beta_0 + \beta_1 aid_{it-2} + \beta_3 X_{it} + \gamma_i + \delta_t + \varepsilon_{it} \quad (1)$$

$$\mathrm{aid}_{it-2} = \alpha_0 + \alpha_1(\mathrm{IPI}_{t-2} * \mathrm{prob}_i) + \alpha_2 X_{it} + \delta_i + \sigma_t + \omega_{it} \quad (2)$$

where Eqs. (1) and (2) are respectively the second and first-stage equations of the 2SLS system. In particular, in Eq. (1) y_{it} is the agricultural productivity (TFP) in recipient

Table 2 Effects of total agricultural aid on TFP

TFP (log)	Total aid (adaptation + mitigation)					
	Total value (log)		Number of projects		Average value (log)	
	(1)	(2)	(1)	(2)	(1)	(2)
Agricultural aid (L2)		0.039**		0.018***		0.064*
		(0.02)		*(0.01)*		*(0.04)*
Instrument (L2)	18.187***		39.212***		11.052**	
	(5.65)		*(6.19)*		*(5.23)*	
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Under identification		9.65		33.29		4.33
Weak identification		10.37		40.09		4.46
N	1170	1170	1170	1170	1170	1170

*Note: Robust standard errors in parentheses. Statistical significance: *** 1%; ** 5%, * 10%. FE stands for fixed effects. The instrument is the US industrial production index (log value, 2-year lag) multiplied by the country's average probability of receiving aid*

country i at year t; aid_{it} denotes agricultural aid received to recipient country i in year t. In this analysis, we consider three different measures of total, adaptation, and mitigation agricultural aid: their logged total financial value, the total number of projects financed each year, and the logged average financial value. All these measures are introduced considering their value two years before so that we let aid have sufficient time to affect agricultural productivity.

X_{it} is a vector of recipient country- year variables of control, that is: broad money, food consumer price index, temperatures, precipitations, political stability, remittances, and trade openness; γ_i and δ_t are the country and year fixed effects (FE), and ε_{it} is the error term.

In Eq. (2), as explained earlier, aid is instrumented with the interaction between the same-year US Industrial Production Index at time t, IPI_{t-2}, and the cross-sectional probability of receiving total, adaptation or mitigation agricultural aid, that is $prob_i$. In Eq. (2) we introduce the same set of controls as of Eq. (1), X_{it}, together with country and year fixed effects (FE), δ_i and σ_t.

β_1 is the coefficient of interest and represents the estimated effect of an additional unit of aid (total financial value, or total number of projects financed each year, or average financial value) on agricultural productivity. A positive coefficient indicates that, on average, an increase in the provision of ODA increases the Total Factor Productivity.

Econometric results

This section reports the empirical results of the analysis. In particular, Eqs. (1) and (2) have been estimated three different times. In the first case, we considered total agricultural aid, so as to assess the aggregate effect of agricultural aid (Table 2). Then, the two equations have been estimated again introducing this time two different types of agricultural aid: mitigation agricultural aid and adaptation agricultural aid (Table 3). Lastly, we performed a third estimation considering exclusively the adaptation component and segmenting recipient countries into four groups based on their climate vulnerability and readiness following the ND-GAIN indicators.

Table 3 Effects of mitigation and adaptation agricultural aid on TFP

TFP (log)	Total value (log)		Number of projects		Average value (log)	
	(1)	(2)	(1)	(2)	(1)	(2)
Mitigation aid						
Agricultural aid (L2)		− 0.202		− 0.083		− 0.916
		(0.31)		*(0.05)*		*(5.53)*
Instrument (L2)	− 3.124		− 7.599*		-0.69	
	(4.72)		*(4.11)*		*(4.20)*	
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Under identification		0.44		3.50		0.03
Weak identification		0.44		3.42		0.03
N	1170	1170	1170	1170	1170	1170
Adaptation aid						
Agricultural aid (L2)		0.008**		0.009**		0.010**
		(0.00)		*(0.01)*		*(0.01)*
Instrument (L2)	54.135***		47.459***		42.938***	
	(3.96)		*(4.73)*		*(3.57)*	
Country FE	Yes	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes	Yes
Under identification		80.52		67.88		69.211
Weak identification		186.90		100.74		144.82
N	1170	1170	1170	1170	1170	1170

*Note:Robust standard errors in parentheses. Statistical significance: *** 1%; ** 5%, * 10%. FE stands for fixed effects. The instrument is the US industrial production index (log value, 2-year lag) multiplied by the country's average probability of receiving aid*

Table 2 reports the results of the two-stage estimates when considering total agricultural aid (their total financial value, the total number of projects financed, and the average value). Specifications (1) and (2) in the columns report the result of the first and second-stage regressions respectively.

The first-stage regressions show an expected positive coefficient of the instrument: increases in the US industrial production index proxy positive business cycles, and encourage donor countries to provide more financial assistance to developing countries. The under-identification (Kleibergen–Paap F-test) is satisfactory for the total number of projects financed, suggesting the strength of our instrument, but is rather weak when the total or average financial values are considered.

The second-stage results indicate that an increase in total agricultural aid increases agricultural TFP in recipient countries. The magnitude of this effect changes depending on the definition of aid considered and ranges from 0.018 for the number of projects to 0.064 when the average value is considered, though in this last case, the effect is significant at only 10%. The effect of the total number of projects is instead statistically significant at 1%.

In order to isolate the effect of mitigation interventions from that of adaptation ones, in the second estimation we decompose total assistance using the Rio markers

Table 4 Effectiveness of agricultural adaptation aid with controls and in sub-samples of countries with different climate vulnerability and readiness

TFP (log)	Entire sample (1)	High vulnerability, low readiness (2)	High vulnerability, high readiness (3)	Low vulnerability, high readiness (4)	Low vulnerability, low readiness (5)
Agricultural aid (log, 2-year lag)	0.008*	0.011*	0.042***	− 0.001	0.038**
	(0.005)	*(0.01)*	*(0.01)*	*(0.01)*	*(0.02)*
Broad money (log, 2-year lag)	0.114***	0.150***	0.232**	0.145**	0.121
	(0.03)	*(0.04)*	*(0.11)*	*(0.06)*	*(0.19)*
Food consumer price index (log, 2-year lag)	0.025	− 0.141***	− 0.371**	0.072	0.143
	(0.029)	*(0.04)*	*(0.19)*	*(0.05)*	*(0.11)*
Temperatures (log)	0.112***	0.466	3.376*	0.098***	− 0.413
	(0.024)	*(0.63)*	*(1.99)*	*(0.02)*	*(0.47)*
Precipitations (log, 1-year lag)	− 0.02	0.07	0.175	− 0.04	− 0.113
	(0.025)	*(0.05)*	*(0.13)*	*(0.03)*	*(0.12)*
Political stability (2-year lag)	0	0.015	0.015	− 0.03	0.039
	(0.011)	*(0.02)*	*(0.05)*	*(0.02)*	*(0.07)*
Remittances (log, 2-year lag)	-0.012	− 0.001	0.056*	0.09	− 0.158
	(0.014)	*(0.02)*	*(0.03)*	*(0.06)*	*(0.11)*
Trade openness (log, 2-year lag)	-0.005	− 0.064***	− 0.188*	0.053	− 0.146
	(0.015)	*(0.02)*	*(0.11)*	*(0.05)*	*(0.15)*
Country FE	Yes	Yes	Yes	Yes	Yes
Time FE	Yes	Yes	Yes	Yes	Yes
Under identification	61.41	15.94	6.35	15.13	4.73
Weak identification	145.22	33.09	17.19	24.96	9.16
N	943	340	125	338	133

*Note: Only second-stage regression results are reported. Robust standard errors are in parentheses. Statistical significance: *** 1%, ** 5%, * 10%. Only the total financial value of agricultural adaptation aid is considered. Countries are classified as high vulnerability or high readiness if their climate vulnerability or readiness exceeds the sample median. A country is classified as high (low) vulnerability and high (low) readiness if it is simultaneously classified as high (low) vulnerability and high (low) readiness*

classification scheme for climate change aid. The results of this analysis are reported in Table 3.

The first-stage regressions for the mitigation agricultural aid indicate an unsatisfactory under identification test and reveal a negative regression coefficient, which is only marginally significant when the number of agricultural mitigation projects is considered. Similarly, in the second stage, we observe that agricultural mitigation aid negatively affects agricultural TFP, though none of the coefficients is statistically significant.

For adaptation agricultural aid, the first-stage regression results and the Underidentification test (Kleibergen-Paap F-test) confirm instead the validity of our instrument. Also, the second stage results indicate that adaptation aid have a positive and statistically significant effect on agricultural productivity growth in each specification considered (total financial value, number of projects, average financial value).

In the last estimation, we focused only on adaptation agricultural aid and its total financial value (Table 4). In this analysis, the control variables typical of the literature on aid effectiveness described in Sect. "Data" are introduced. The effectiveness of agricultural adaptation aid is initially tested on the entire sample. Then, we exploit the ND-GAIN matrix that divides countries into four different groups, depending on their combination of climate vulnerability and climate readiness (see Fig. 2). In particular, the following groups are identified: high vulnerability and low readiness; high vulnerability and high readiness; low vulnerability and high readiness; low vulnerability and low readiness.

When the entire sample is considered (regression 1 of Table 4), the validity of the instrument is highly satisfactory, and the effectiveness of adaptation agricultural aid is found to be robust to the introduction of the different control variables. The regression coefficient, though significant at 10%, is in fact equal to 0.008, in line with the regression coefficients observed in the baseline specification of Table 3. The only control variables that positively and significantly affect agricultural TFP are temperatures and money supply.

The empirical specifications 2–5 of Table 4 allow us to evaluate and compare the effectiveness in recipient countries with different combinations of vulnerability and readiness. The values of the under-identification test show that our instrument explains aid in specifications 2, 3, and 4 but not in specification 5.[1] Aid is effective in all sub-samples, with the exception of low vulnerability and high readiness countries (specification 4), i.e., in those countries that are more equipped to deal with climate change. In terms of magnitude, results are highly heterogeneous. The effectiveness of aid in more vulnerable and less ready countries (regression 2) is the lowest (0.011) one. The coefficient increases noticeably in specification 3 (0.042), i.e., in the sub-samples of high vulnerability—high readiness countries.

With regard to the control variables, which will be discussed in more detail in the next session, it was found that money supply exerts a positive effect in all specifications considered, apart from the specification on the sub-sample of low vulnerability and low readiness countries. The Food Consumer Price Index only negatively affects agricultural TFP in specifications 2 and 3, that is, in highly vulnerable countries. In specifications 3 and 4, the coefficient of temperatures is positive and significant, whereas precipitations are always non-significant in all specifications. Non-significant coefficients are also found in all equations for the variable expressing political stability. Remittances only partially increase agricultural TFP in the sample of high vulnerability and high readiness countries (specification 3). In the other country classifications, remittances have no effect on agricultural TFP. Last, trade openness reduces agricultural productivity in both sub-samples of vulnerable countries, regardless of their climate readiness (specifications 2 and 3).

[1] As for specification (3), the F-statistic is equal to 6.4 and larger than the Stock Yogo critical value (5.53) for a 25% distortion. Hence, we can reject the null hypothesis that the maximum size distortion is greater than 25%.

Discussion

Our analysis sheds some light on the debate about the economic impact of ODA, showing that agricultural aid has a positive effect on agricultural productivity. Our results are robust to the use of different measures of aid adopted (total financial value, number of projects, average financial value) as there is no significant difference across the measures considered. This finding appears to align with a segment of the literature that identifies a positive correlation between international aid and agricultural productivity (Norton et al. 1992; Alabi 2014; Ssozi et al. 2019; Kornher et al. 2021) or, more broadly, with economic growth (Arndt et al. 2010; Galiani et al. 2017; Mary & Mishra 2020). Nonetheless, our study has endeavoured to add a climate change perspective to the results, a dimension previously absent in the existing literature, with the aim of enriching the ongoing discourse. In pursuit of this objective, we have observed that results remain stable when we differentiate agricultural aid into the two Rio Marker climate change components: a closer inspection of adaptation agricultural aid reveals in fact that it remains effective at stimulating agricultural growth in recipient countries. On the other hand, agricultural mitigation aid has no short-term effect on agricultural productivity. This latter outcome is not surprising considered that mitigation aid, by its intrinsic nature, does not aim at increasing agricultural productivity, but rather acts like as a potential competitor for resources needed for agriculture. Responding to climate change through the deployment of low-emission agricultural technologies would put pressure on food security through the potential reduction of food production.

Our work also shows the relevance of the starting conditions of countries receiving subsidies in adaptation, as reported by numerous studies in the literature (Hudson and Mosley 2001; Dalgaard et al. 2004; Mosley et al. 2004). The first group of countries analysed is the most vulnerable and least ready, also in great need of investment to improve readiness and with great urgency for adaptation action. Despite their most unfavourable starting conditions (i.e., reduced capacity to react and severe exposure to the intemperance of climate change), this group is yet able to exploit the benefits of aid, which increase agricultural productivity, albeit to a lesser extent than other countries. It should be noted, moreover, that in these countries the ratio of agricultural value added to GDP exceeds 40 percent, so the increase in productivity in agriculture affects directly the entire economy of the country. This is an important message for donors, who should not be discouraged from allocating aid to these countries, mainly located in Sub-Saharan Africa but also in the Middle East and in Latin America (see Table 6 in Appendix).

Our analysis indicates also that climate readiness is the key element for successfully transforming received aid into actual agricultural growth: in most vulnerable countries but with high levels of climate readiness, the impact of agricultural aid on agricultural productivity is the highest. This should come as no surprise since readiness reflects the ease of doing business and measures a country's ability to leverage investments and transform the same into adaptation intervention, taking into account economic, governance, and social variables.

A noteworthy finding pertains to the effectiveness of aid in facilitating adaptation in countries with low vulnerability levels. In this scenario, foreign aid appears to exert a not significant influence on the growth of agricultural productivity. This observation holds true for countries with both high and low readiness levels. Additionally, in the formers, a significant proportion of these countries (see Fig. 2 and Table 6 in the Appendix) report a lower quota contribution of agricultural Value Added relative to their Gross Domestic Product (GDP).

As for the control variables, we observe that money supply generally has a positive role in stimulating agricultural productivity: a larger money supply tends to reduce the interest rate, thus favouring investment and capital accumulation. Altogether, these elements could foster agricultural productivity. Greater trade openness tends instead to reduce agricultural productivity in the most vulnerable countries, regardless of their level of readiness. This could be caused by a number of factors as increased competition from imports; a shift to non-agricultural sectors and a lack of investment in agriculture from both the private and public sectors. With regard to food consumer prices, price variation appears significant only in the most vulnerable countries and has a negative impact: higher food prices reduce productivity growth. Food prices are strictly related to agricultural productivity: rising food prices can motivate farmers to increase their market participation (especially when they generally are subsistence-orientated) and to invest in agricultural technologies that can increase in turn agricultural productivity (Benfica et al. 2017). Nonetheless, during the food price crises of 2008, many developing countries reduced their agricultural trade surplus and eventually became food net importers: local rural farmers, typically constrained by small landholdings and input costs, and distant from markets (Wodon and Zaman 2010), and were not in fact flexible enough to respond to the change in agricultural relative prices (Pingali 2007a). Hence, in those low-income countries that largely rely on agriculture as a source of income, high food prices reduce farmers' investment capacities and thus the chances to experience agricultural productivity growth. It is nonetheless worth stressing that the overall effect of increased food prices is that of impoverishing poor households and exacerbating food insecurity (Ivanic and Martin 2008; Warr 2014).

Focusing on weather, temperatures might positively influence agricultural productivity, though the effect is mainly limited to low vulnerable countries that are less exposed to heatwaves. It is worth stressing that this definition of temperature simply refers to average temperatures, and does not identify temperature shocks.

Concluding remarks

The agricultural sector is facing different challenges. Weather conditions are threatening entire crops in both advanced and developing countries. In this context, foreign aid and development assistance become more and more relevant to preserve productivity and minimize food insecurity.

Considering that developing countries, and their agricultural sectors, are among the most vulnerable to climate change, it is important to analyze the actual effectiveness of international aid. Provided that the available evidence is often contrasting, this paper aims to contribute to the existing debate on aid effectiveness focusing on the impact of agricultural subsidies on agricultural productivity growth from a climate perspective.

To this purpose, we adopt the Rio Marker 2010 classification system that distinguishes aid into adaptation and mitigation to climate change, and we perform a two-stage instrumental variable approach to account for the potential endogeneity that aid could have on recipient countries' agricultural productivity. We build a sample of 115 recipient countries and evaluate how instrumented agricultural adaptation and mitigation aid differently impact the agricultural Total Factor Productivity in the short-medium run.

To further advance the analysis of aid effectiveness, we have classified the recipient countries into four sub-groups based on indicators developed by ND-GAIN index, which primarily considers their vulnerability and preparedness towards climate change.

Our findings confirm that aid in agriculture has a positive impact on agricultural productivity, with a significant role played by aid in adaptation. We also found an interesting relationship between the starting characteristics of the recipient countries and aid effectiveness.

Specifically, countries that have a higher readiness and high vulnerability to climate change tend to benefit the most from aid, while those that are more vulnerable to climate change and with low readiness are not able to leverage the aid received to the same extent. Nevertheless, it is worth noting that even in these vulnerable countries, the relationship between aid and growth remains positive.

The results of this analysis not only confirm the importance of global international aid to agriculture but also suggest the importance of distinguishing between adaptation and mitigation flows. A more precise definition of aid may indeed improve aid impact analyses, providing more accurate results than in the past.

However, it is important to acknowledge certain limitations in this work. Firstly, although the utilization of an aggregate indicator like agricultural TFP enabled us to conduct a cross-country analysis, the model employed does not facilitate an exploration of the partial productivity dynamics of individual production factors. Additionally, our analysis was exclusively centred on the agricultural sector, without considering the potential reallocation of factors of production to other productive sectors. This aspect assumes particular significance for less developed countries, where agricultural labour permanently exhibits lower productivity compared to other economic sectors. In future research, it would be valuable to investigate whether international aid also exerts an influence on the broader economy in these countries.[2]

Future work could also explore the effectiveness of adaptation aid in hot and dry countries, and assess the capacity of stabilizing agricultural productivity also following extreme weather events, such as temperatures heatwaves or droughts. In addition, given that the impact of aid tends to accumulate over the long term, it would be beneficial to extend the time period under consideration and employ models that capture the cumulative effect of aid.

[2] We express our gratitude to the anonymous reviewer for their valuable insight into this aspect.

Appendix

See Tables 5 and 6.

Table 5 List of recipient countries included in the sample by geographical region

Country	Geographical region
Cambodia; China; Fiji; Indonesia; Lao PDR; Malaysia; Mongolia; Myanmar; Papua New Guinea; Philippines; Solomon Islands; Thailand; Timor-Leste; Vanuatu; Vietnam	East Asia and Pacific
Albania; Armenia; Azerbaijan; Belarus; Bosnia and Herzegovina; Georgia; Kazakhstan; Moldova; Montenegro; Serbia; Tajikistan; Turkey; Turkmenistan; Ukraine; Uzbekistan	Europe and Central Asia
Argentina; Belize; Bolivia; Brazil; Colombia; Costa Rica; Cuba; Dominican Republic; Ecuador; El Salvador; Guatemala; Guyana; Haiti; Honduras; Jamaica; Mexico; Nicaragua; Paraguay; Peru; Suriname; Venezuela, RB	Latin America and Caribbean
Algeria; Djibouti; Egypt, Arab Rep; Iran, Islamic Rep; Iraq; Jordan; Lebanon; Libya; Morocco; Syrian Arab Republic; Tunisia; West Bank and Gaza; Yemen, Rep	Middle East and North Africa
Afghanistan; Bangladesh; Bhutan; India; Nepal; Pakistan; Sri Lanka	South Asia
Angola; Benin; Botswana; Burkina Faso; Burundi; Cabo Verde; Cameroon; Central African Republic; Chad; Comoros; Congo, Dem Rep; Congo, Rep; Cote d'Ivoire; Equatorial Guinea; Eritrea; Eswatini; Ethiopia; Gabon; Gambia, The; Ghana; Guinea; Guinea-Bissau; Kenya; Lesotho; Liberia; Madagascar; Malawi; Mali; Mauritania; Mozambique; Namibia; Niger; Nigeria; Rwanda; Sao Tome and Principe; Senegal; Sierra Leone; Somalia; South Africa; South Sudan; Sudan; Tanzania; Togo; Uganda; Zambia; Zimbabwe	Sub-Saharan Africa

Table 6 List of recipient countries classified depending on their vulnerability and readiness

	ND-GAIN climate matrix
Bangladesh, Bhutan, Ghana, India, Namibia, Nepal, Nigeria, Pakistan, Rwanda, Sao Tome and Principe, Solomon Islands, Somalia, South Sudan, Sri Lanka, St Vincent and the Grenadines, Timor-Leste, Vanuatu, Vietnam, West Bank and Gaza	High vulnerability, high readiness
Afghanistan, Angola, Benin, Bolivia, Burkina Faso, Burundi, Cambodia, Cameroon, Central African Republic, Chad, Comoros, Congo, Dem Rep, Congo, Rep, Cote d'Ivoire, Djibouti, Eritrea, Eswatini, Ethiopia, Gambia, The, Guinea, Guinea-Bissau, Guyana, Haiti, Honduras, Kenya, Lao PDR, Liberia, Madagascar, Malawi, Mali, Mauritania, Mozambique, Myanmar, Niger, Papua New Guinea, Philippines, Senegal, Sierra Leone, Sudan, Tanzania, Togo, Uganda, Yemen, Rep, Zambia, Zimbabwe	High vulnerability, low readiness
Albania, Argentina, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Botswana, Brazil, Cabo Verde, China, Colombia, Costa Rica, Cuba, Dominican Republic, Egypt, Arab Rep, El Salvador, Fiji, Georgia, Indonesia, Iran, Islamic Rep, Jamaica, Jordan, Kazakhstan, Malaysia, Mexico, Moldova, Mongolia, Montenegro, Morocco, Paraguay, Peru, Serbia, South Africa, Thailand, Tunisia, Turkey, Ukraine	Low vulnerability, high readiness
Algeria, Belize, Ecuador, Equatorial Guinea, Gabon, Guatemala, Iraq, Lebanon, Lesotho, Libya, Nicaragua, Suriname, Syrian Arab Republic, Tajikistan, Turkmenistan, Uzbekistan, Venezuela	Low vulnerability, high readiness

Source: The Notre Dame Global Adaptation Initiative's (ND-GAIN)

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