The Green Revolution and Infant Mortality

Evidence from 600,000 Births

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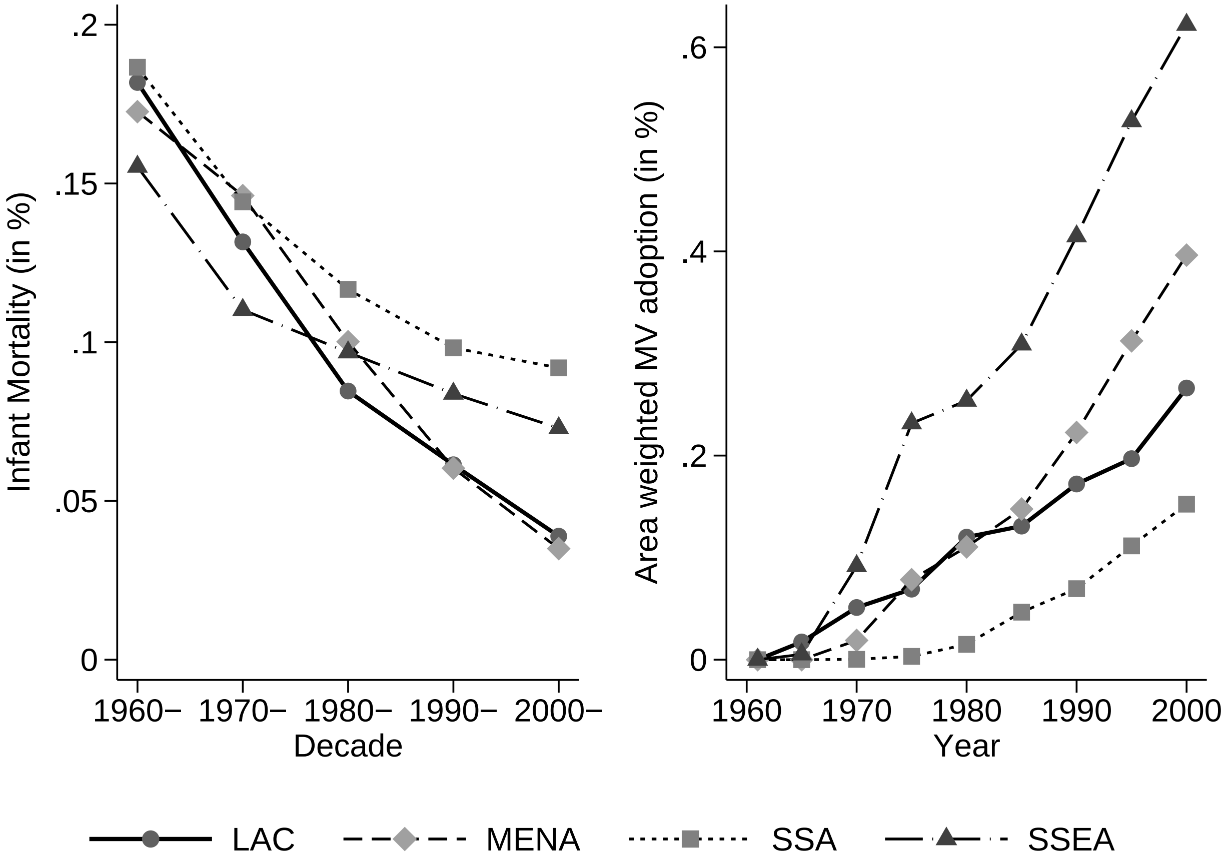
Outline

Motivation

Motivation

- The Green Revolution is arguably one of the most significant economic transformations of the 20th century
    - More than 8,000 modern varieties (MVs) released over the past 40 years and sown over much of the global cultivated area (World Bank, 2008)
- Thought to have led to major improvements in productivity, income, food security and health in developing countries (Evenson and Gollin, 2003; Bustos et al., 2016; McArthur and McCord, 2016)
- In recent years, renewed debate on:
    - The role of agriculture in development
    - The impact of agricultural productivity gains on food security, nutrition and health
    - The efficient levels of public investment in agricultural R&D and technology diffusion

Infant Mortality and MV Adoption, by region



Motivation

- Estimating the causal impact of the GR is challenging:
  - Large scale, gradual transformation
  - Severe data limitations
  - (Development and) Adoption of MVs is endogenous, creating potentially spurious correlations with economic or health outcomes.
  - Large potential spillover effects.

Motivation

- Most evidence limited to:
  - Mostly country level correlations (including panels) of MV adoption and agricultural productivity (Evenson and Gollin, 2003; Walker and Alwang, 2015)
  - Relatively small number of experimental or quasi-experimental localised studies of impacts on food security (Stewart et al, 2015)
- Country level relationships could be biased by various policy and economic confounders.
- At the country level, no evidence for negative relationship between infant mortality and MV diffusion.

This Paper

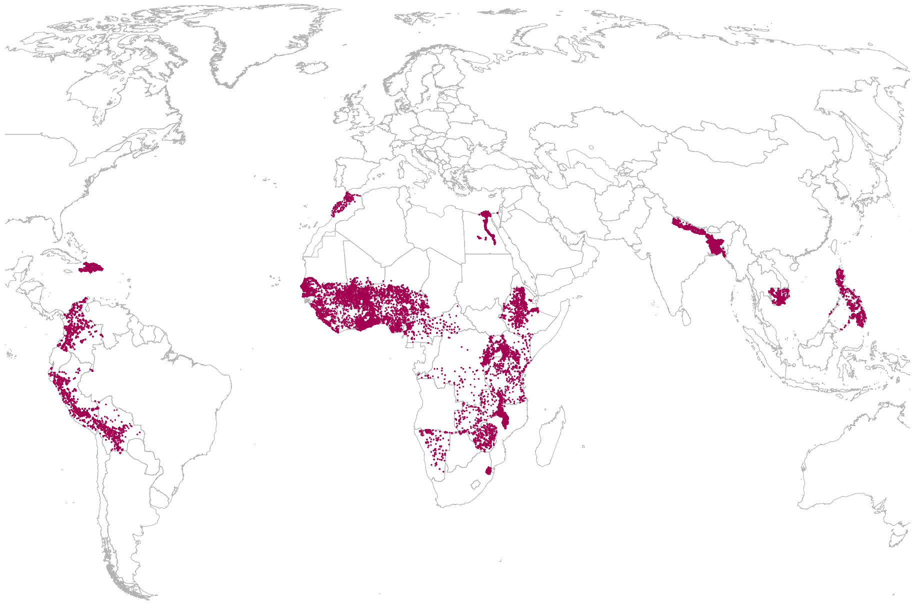
- Attempts to improve quality of global scale inference of the health impacts of MV adoption
- Examines correlations at sub-national, fine spatial and temporal scales, controlling for all country level processes
  - Constructs time-varying and spatially explicit, sub-national indicators of MV coverage
  - Uses DHS data to construct a panel of child births and mortality at the village level
  - Constructed sample contains approx. 18,000 rural villages spread across spread across 400 administrative regions in 36 countries

Data

Infant Mortality (from Demographic and Health Surveys)

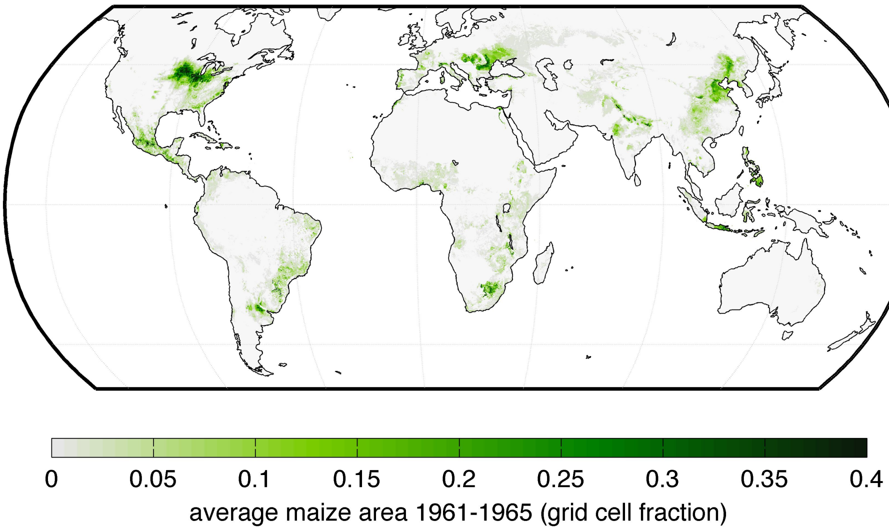
- Reconstructed village-birth year child level panel containing $>$600,000 rural births from 1950 to 2012

Figure 1: Location of DHS sampling clusters in rural areas



Ray et al. (2012) provide cultivated areas of 4 cereals (Maize, Rice, Wheat and Soybeans) from 1961 to 2008

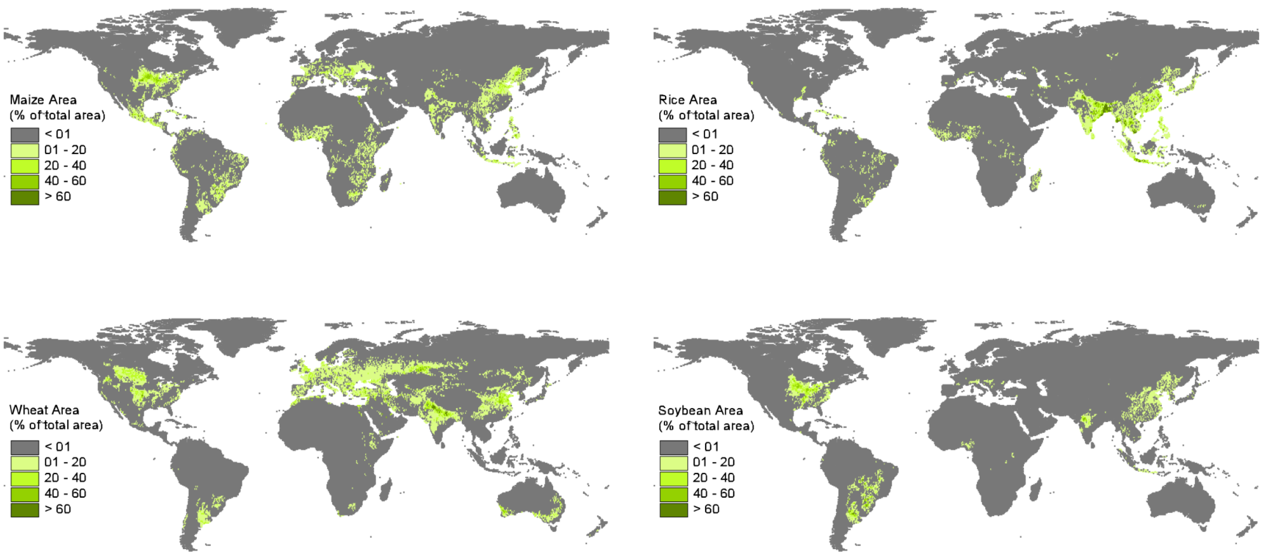
Figure 2: Average maize area, 1961-65 (as fraction of grid cell)



- Resolution: 5 arc minute (10 × 10 km at the equator)

Monfreda et al. (2008) provide cultivated areas for 175 Crops circa 2000

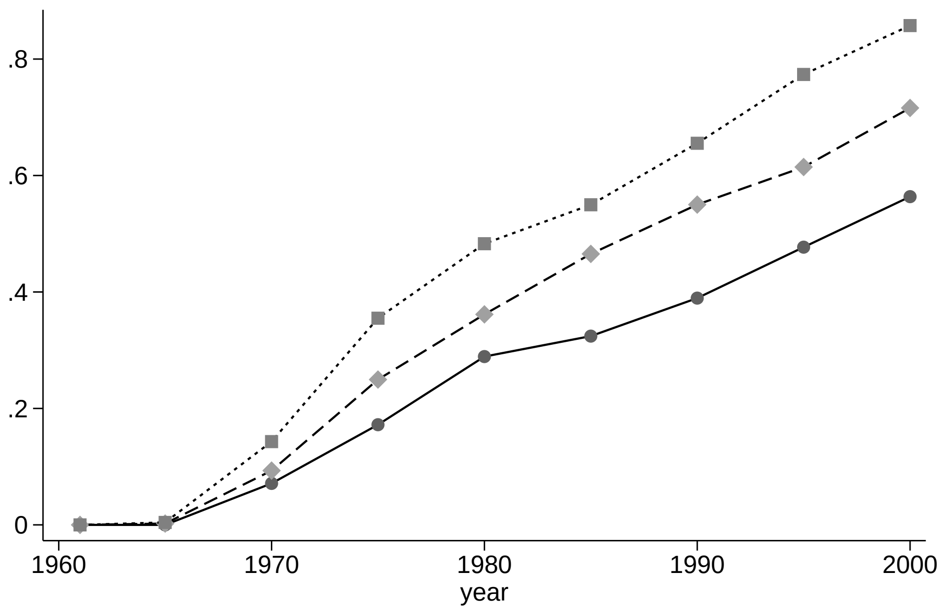
Figure 3: Harvested areas for 4 crops in 2000 (as % of total area)



Area under Improved Varieties

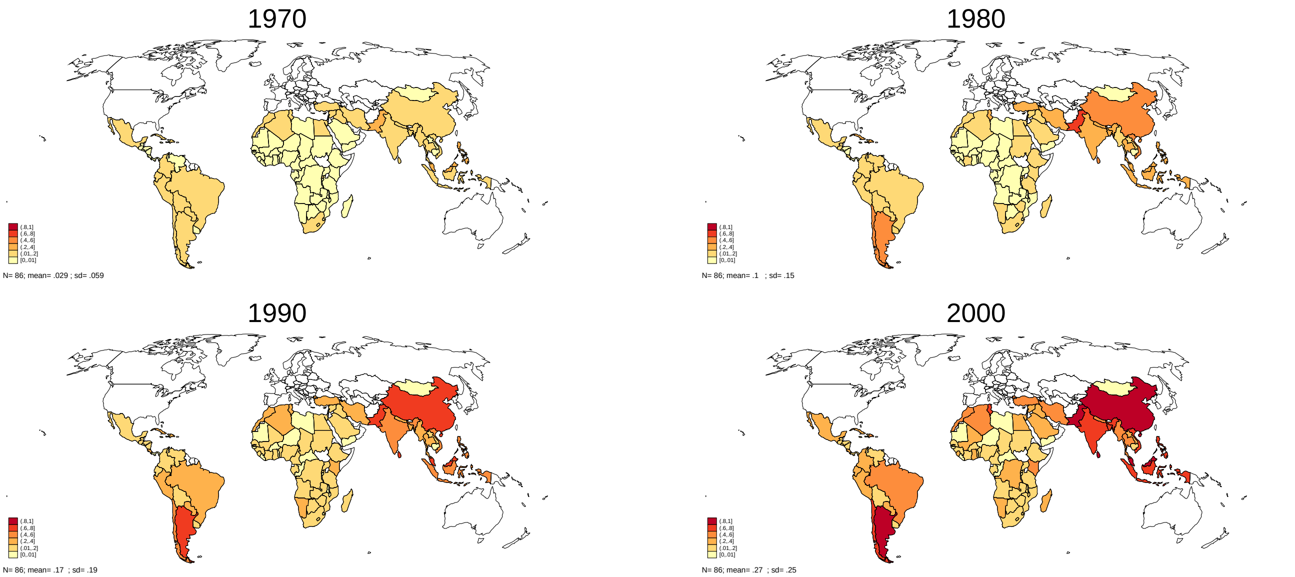
- Evenson and Gollin (2003) provide country × year × crop data on the fraction of area planted with modern varieties.
- 11 major crops, 90 countries, 1960 to 2000

Figure 4: Area weighted MV adoption for 3 crops, 1960-2000 (in %)



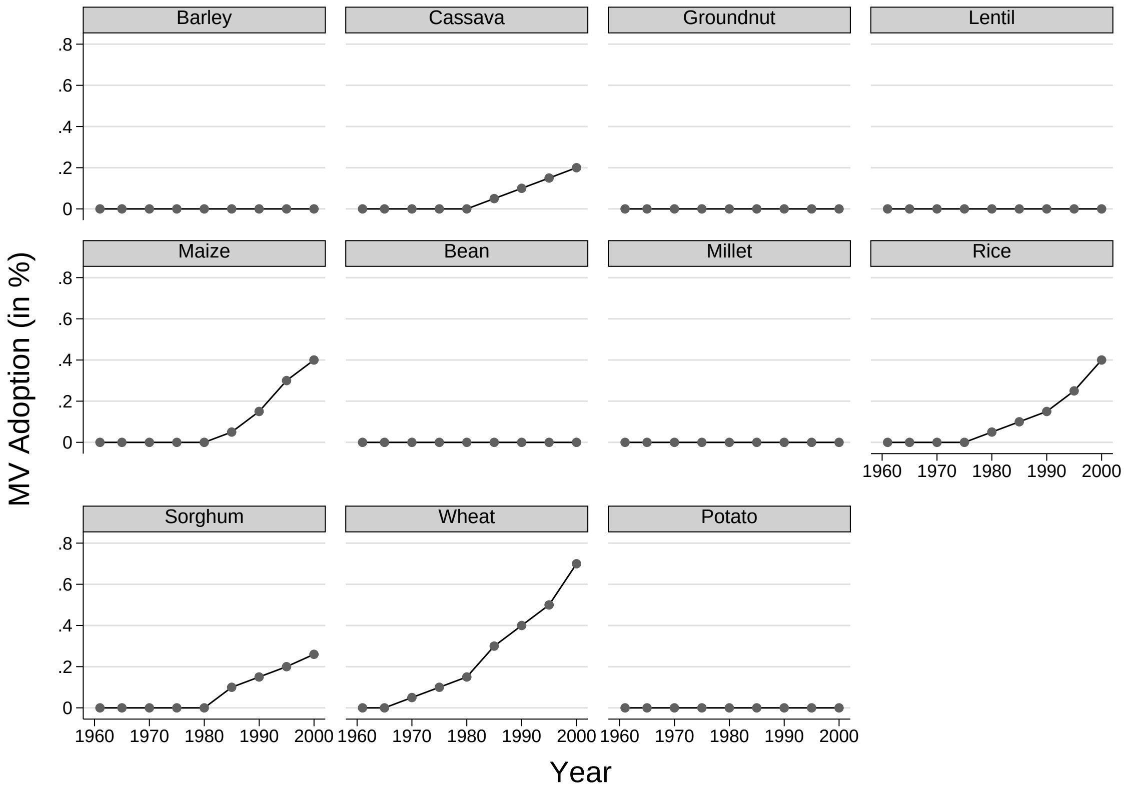
Geographical Coverage of MV Adoption

Figure 5: Area weighted MV adoption for 11 crops, 1970-2000 (in %)



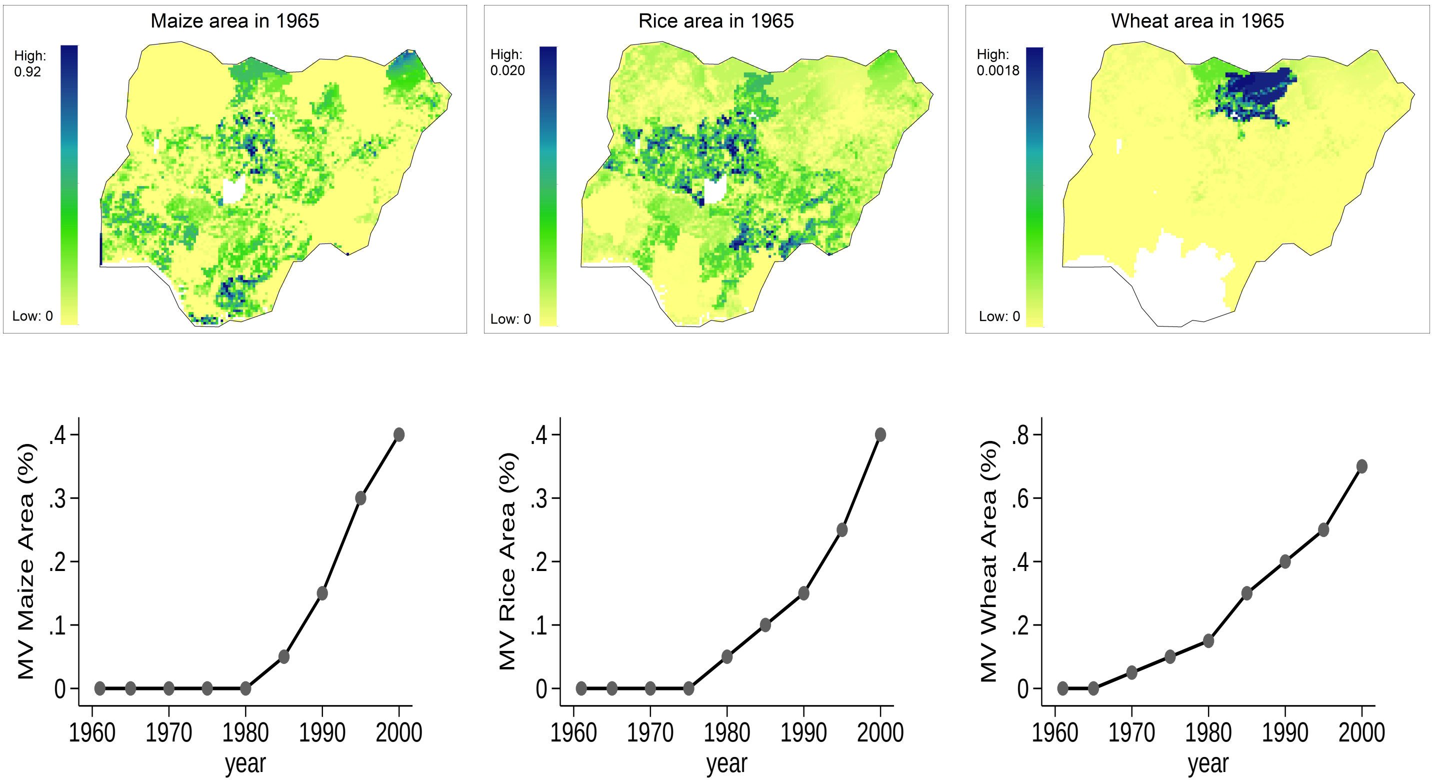
A Country Example

Figure 6: Crop wise MV adoption in Nigeria, 1960-2000 (in %)



Empirical Strategy

Constructing the ‘treatment’ variable (Nigeria as an example)



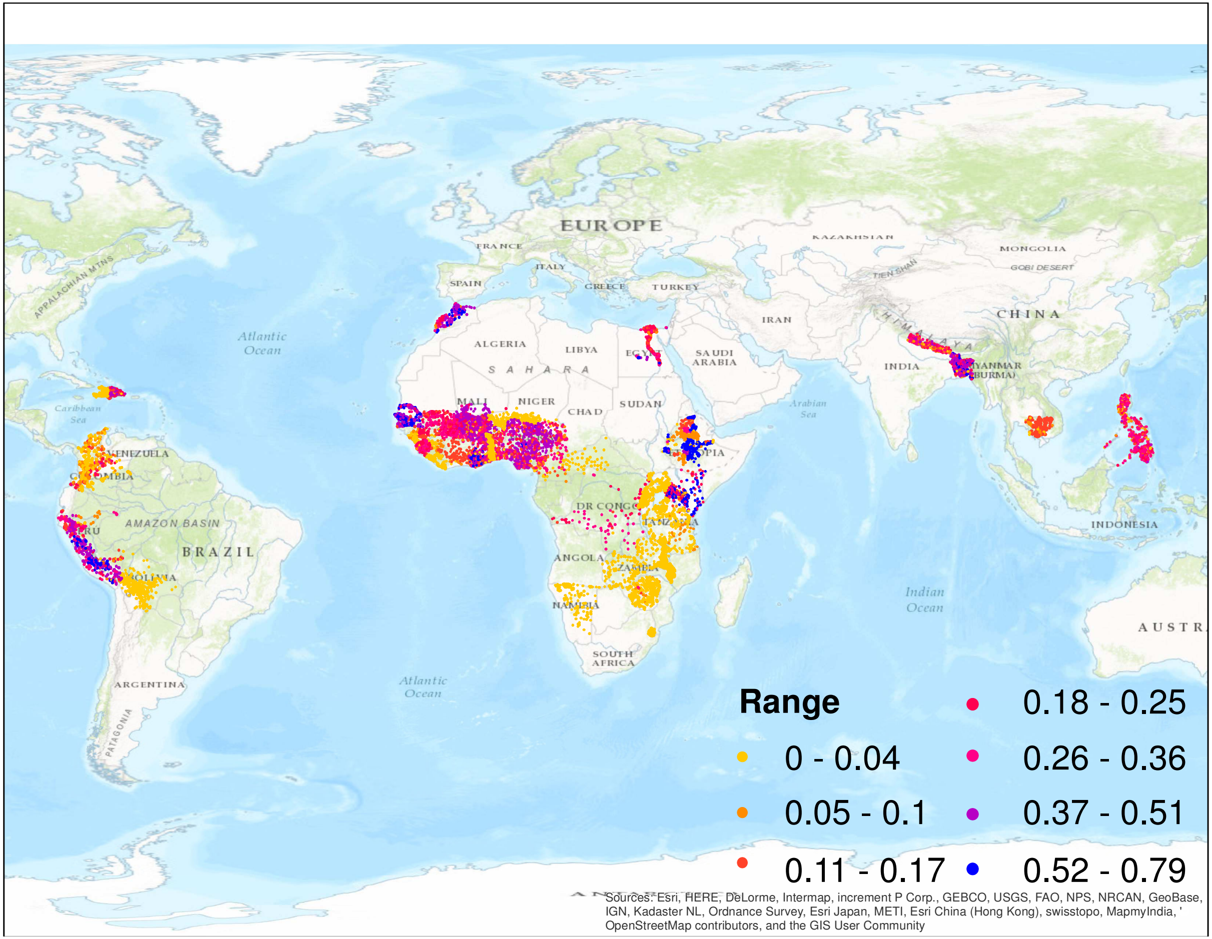
Treatment Variable - 1

For village v in country c at time t, define:

$$MV \times 1961\text{-}65area_{vct} = \frac{\sum_j^3 (CropAreain1961\text{-}65_{jvct} \times MVArea_{jct})}{\sum_j^3 CropArea_{jvct}} \tag{1}$$

$j \in \{Maize, Rice, Wheat\}$.

Figure 7: Percentage point change in (MV × 1961-65 Area) over time



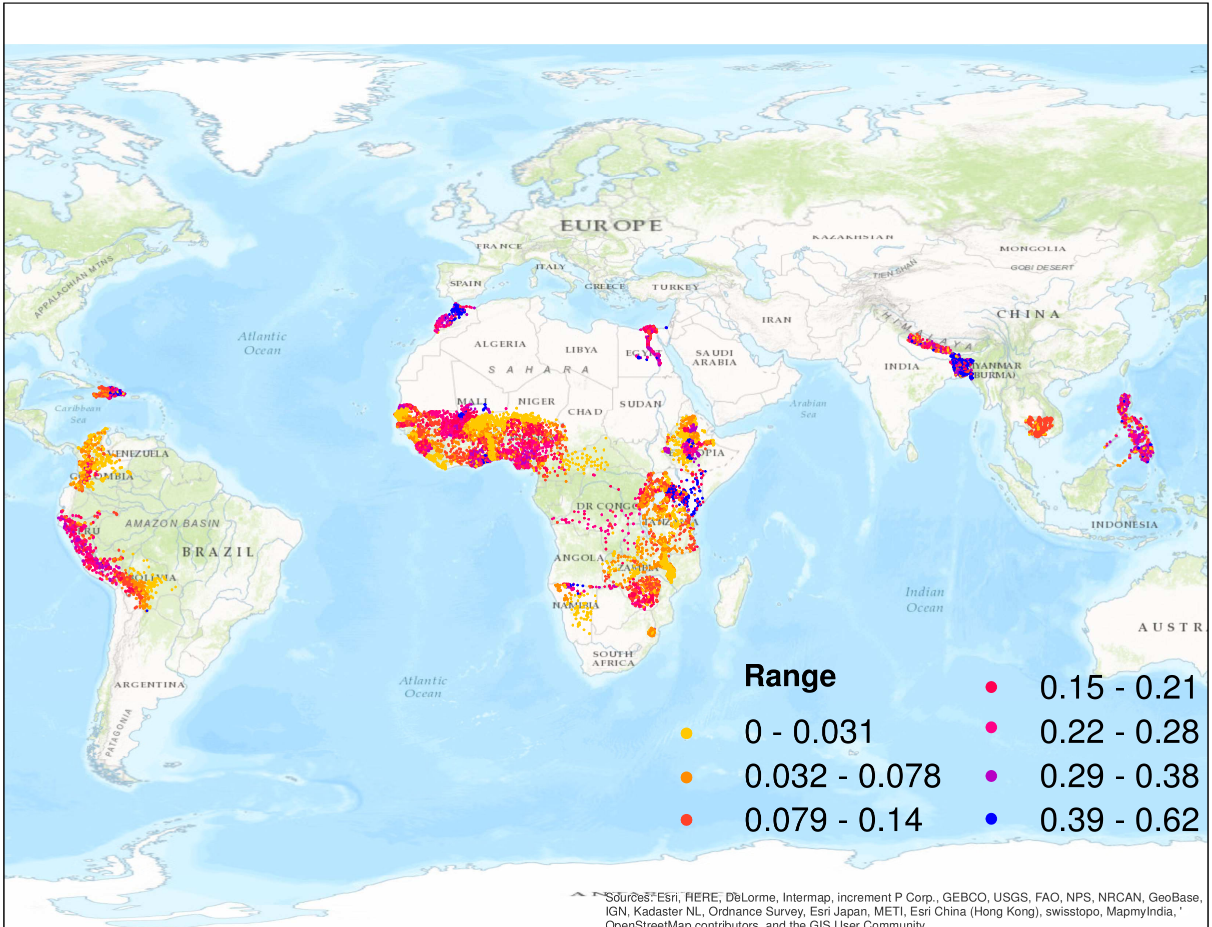
Treatment Variable - 2

For village v in country c at time t, define:

$$MV \times 2000area_{vct} = \frac{\sum_j^{11}(CropAreain2000_{jvc} \times MVArea_{jct})}{\sum_j^{11} CropArea_{jvc}} \quad (2)$$

$$j \in \{Barley, Bean, Cassava, Groundnut, Lentil, Maize, Millet, Potato, Rice, Sorghum, Wheat\}$$

Figure 8: Percentage point change in (MV × 2000 Area) over time



Identification Strategy

$$y_{ivct} = \gamma(MV \times Area)_{vct} + u_v + Z_{ct} + X_{ivct} + e_{ivct} \qquad (3)$$

where, y_{ivct} is a binary indicator of infant mortality (death in the first year of life) i.e. whether child i in village v in country c died in its birth year t

- u_v are village fixed effects and Z_{ct} are country-year FE
- X_{ivct} includes quadratic in mother's age (at birth of child) and sex of child
- e_{ivct} clustered at subnational (admin) level
- Sample restricted to rural villages and mothers who report to have never migrated

Identification Strategy

- Examines whether parts of the country where MVs were faster adopted display faster than average reductions in infant mortality
- Controlling for flexible country $\times$ birth year FE absorbs all economic and policy changes at the country level
- Only identifies effects occurring due to:
    - Income increases for farmers
    - Localised increases in food availability resulting from limited market connectivity

Concerns re Identification

- **Concern**: Could we be conflating the effect of MV with effects related to use of specific crops operating through non-MV channels?
- **"Solution"**: Controlling for Crop Areas $\times$ Year $\times$ Region does not alter the results.
- **Concern**: Does not fully address potential local endogeneity of MV adoption.
- **"Solution"**:Controlling for geography (distance to coast and cities) $\times$ flexible time trends does not alter the results.
- Currently examining "balance" pre-MV diffusion....

Findings

Table 1: Impact on infant mortality

	(1)	(2)	(3)
Panel A: All			
MV × 2000 area	−0.0633		
	(0.0266)**		
MV × 1961-65 area		−0.0542	−0.0553
		(0.0165)***	(0.0172)***
N	580,805	567,941	518,179
Panel B: Girls			
MV × 2000 area	−0.0212		
	(0.0365)		
MV × 1961-65 area		−0.0238	−0.0291
		(0.0228)	(0.0248)
N	282,395	276,160	251,790
Panel C: Boys			
MV × 2000 area	−0.0939		
	(0.0309)***		
MV × 1961-65 area		−0.0859	−0.0797
		(0.0185)***	(0.0175)***
N	297,083	290,475	265,271
Geog controls	No	No	Yes

Note: Geographic controls include distance to coast × region × year FE and distance to cities × region × year FE. The mean for overall infant mortality is 0.1, for girls it is 0.098 and for boys it is 0.11.

Region-specific results

Table 2: Impact of MV (Crop area in 1961-65 x MV) on infant mortality, by region

	(1) LAC	(2) MENA	(3) SSA	(4) SSEA
All	−0.1493	−0.2367	−0.0280	0.1360
	(0.0643)**	(0.0663)***	(0.0125)**	(0.1173)
N	76,224	119,047	316,728	55,942
Girls	−0.1074	−0.1953	0.0023	−0.0386
	(0.0764)	(0.0891)**	(0.0209)	(0.1618)
N	37,044	57,469	154,458	27,189
Boys	−0.2156	−0.2873	−0.0571	0.2084
	(0.0884)**	(0.0621)***	(0.0141)***	(0.1757)
N	38,770	61,520	161,675	28,510

Note: LAC includes 5 countries, North Africa 2 countries, SSA 25 countries and SSEA 4 countries.

Crop-specific Results

Table 3: Impact of (respective) crop area in 2000 x MV on infant mortality

	(1) Cereals	(2) Maize	(3) Millet	(4) Rice	(5) Sorghum	(6) Wheat
All	−0.0489	−0.0022	−0.2351	0.1305	−0.4075	−0.0792
	(0.0192)**	(0.1069)	(0.3957)	(0.0614)**	(0.0697)***	(0.0477)*
N	580,495	629,664	629,664	629,664	629,664	629,664
Girls	−0.0111	−0.0965	−0.4989	0.2233	−0.3128	−0.0783
	(0.0255)	(0.1358)	(0.6119)	(0.0726)***	(0.0835)***	(0.0492)
N	282,258	306,377	306,377	306,377	306,377	306,377
Boys	−0.0802	0.1771	0.0627	0.0936	−0.5116	−0.0895
	(0.0227)***	(0.1409)	(0.7163)	(0.0805)	(0.0676)***	(0.0561)
N	296,923	321,823	321,823	321,823	321,823	321,823

Crop-specific Results

Table 4: Impact of crop area in 2000 x MV on infant mortality

	(1) Cereals	(2) Maize	(3) Millet	(4) Rice	(5) Sorghum	(6) Wheat
All	−0.0489	−0.0159	−0.172	0.0747	−0.426	0.0373
	(0.0192)**	(0.112)	(0.397)	(0.0557)	(0.0729)***	(0.0663)
N	580,495	629,664	629,664	629,664	629,664	629,664
Girls	−0.0111	−0.134	−0.467	0.196	−0.262	−0.00977
	(0.0255)	(0.143)	(0.616)	(0.0734)***	(0.0859)***	(0.0623)
N	282,258	306,377	306,377	306,377	306,377	306,377
Boys	−0.0802	0.177	0.156	0.00245	−0.579	0.0725
	(0.0227)***	(0.143)	(0.713)	(0.0764)	(0.113)***	(0.0888)
N	296,923	321,823	321,823	321,823	321,823	321,823

Summary so far

- We use rich subnational data to study the differential impact of MVs on infant mortality of boys and girls in 36 developing countries
- Preliminary results suggests that a 25 percentage point expansion of area planted to MVs is associated with a decline of 1.2-1.5 percentage points in infant mortality
- Robust to weighted average of cereal (5 crop) areas in 2000 $\times$ MV
- Robust to several tests, and across regions (except Asia)

Additional Analysis (in progress)

- Next steps:
  - Mother fixed effects
  - Improve inference by using data on timing of releases (DIIVA) for “less endogenous” temporal variation
  - Improve inference by using agro-ecological (GAEZ) suitability for exogenous spatial variation in crop choice
  - Improve inference by using agro-ecological (GAEZ) suitability for exogenous spatial variation in MV
  - Country case study

Using DIIVA in SSA - Preview of Status of Results

- Diffusion and Impacts of Improved Varieties in Africa (DIIVA) focusses on Sub-Saharan Africa and provides following estimates:
  - National adoption percentage in 2009
    - Used to extend sample
    - Result: results disappear
  - Aggregate number of releases by crop-country-year
    - Use variation in releases to replace MV diffusion data from EG
    - Results disappear when using cumulative releases
    - Note: mixed correlations between these release variables and MV diffusion at country level

Table 5: Impact on infant mortality in SSA, 1961-2008 (extension using DIIVA)

	(1)	(2)	(3)
Panel A: All			
MV × 2000 area	0.0278		
	(0.0254)		
MV × 1961-65 area		0.0031	0.0088
		(0.0153)	(0.0207)
N	381,504	368,291	330,813
Panel B: Girls			
MV × 2000 area	0.0468		
	(0.0295)		
MV × 1961-65 area		0.0081	0.0201
		(0.0184)	(0.0253)
N	186,410	180,006	161,571
Panel C: Boys			
MV × 2000 area	0.0156		
	(0.0333)		
MV × 1961-65 area		−0.0043	−0.0034
		(0.0209)	(0.0245)
N	194,647	187,843	168,875
Geog controls	No	No	Yes

Note: Geographic controls include distance to coast × region × year FE and distance to cities × region × year FE.

Treatment Variable based on Cumulative Releases

For village v in country c at time t, define the following measures:

$$Releases{\times}1961\text{-}65area_{vct} = \frac{\sum_j^3 (CropAreain1961\text{-}65_{jvc} \times Releases_{jct})}{\sum_j^3 CropArea_{jvc}} \tag{4}$$

$$Std.releases{\times}2000area_{vct} = \frac{\sum_j^{11} (CropAreain2000_{jvc} \times Std.releases_{jct})}{\sum_j^{11} CropArea_{jvc}} \tag{5}$$

where, standardized releases are the number of releases normalized by the total number of releases in SSA

Table 6: Reduced form impact on infant mortality in SSA (using MV releases), 1961-2000

	(1)	(2)	(3)
Panel A: All			
Releases × 2000 area	6.8×10^{-06}		
	(.00021)		
Releases × 1961-65 area		−.00018	−.00024
		(.00016)	(.00017)
N	317,517	300,839	274,681
Panel B: Girls			
Releases × 2000 area	0.00026		
	(.00034)		
Releases × 1961-65 area		−.00025	−.00047
		(.00026)	(.00024)**
N	154,776	146,661	133,794
Panel C: Boys			
Releases × 2000 area	−.00012		
	(.0004)		
Releases × 1961-65 area		0.000049	0.00015
		(.00041)	(.00041)
N	162,189	153,636	140,441
Geog controls	No	No	Yes

Note: Geographic controls include distance to coast × region × year FE and distance to cities × region × year FE.

Table 7: Reduced form impact on infant mortality in SSA (using normalized/ standardized MV releases), 1961-2000

	(1)	(2)	(3)
Panel A: All			
Std. releases × 2000 area	−0.0036		
	(0.0053)		
Std. releases × 1961-65 area		−0.0039	−0.0050
		(0.0036)	(0.0037)
N	317,517	300,839	274,681
Panel B: Girls			
Std. releases × 2000 area	−0.0047		
	(0.0056)		
Std. releases × 1961-65 area		−0.0034	−0.0076
		(0.0060)	(0.0054)
N	154,776	146,661	133,794
Panel C: Boys			
Std. releases × 2000 area	0.0003		
	(0.0094)		
Std. releases × 1961-65 area		0.0003	0.0017
		(0.0083)	(0.0082)
N	162,189	153,636	140,441
Geog controls	No	No	Yes

Note: Geographic controls include distance to coast × region × year FE and distance to cities × region × year FE.

Association between MV areas and Releases

Table 8: Relationship between MV areas and cumulative releases, 1961-2000

	(1) Cassava	(2) Maize	(3) Millet	(4) Rice	(5) Sorghum
Panel A:					
Releases	0.0039	0.0016	0.0003	0.0012	0.0026
	(0.0021)*	(0.0021)	(0.0019)	(0.0015)	(0.0026)
N	224	222	225	216	223
# Countries	25	25	25	25	25
Avg yr.	9	8.9	9	8.6	8.9
Panel B:					
Std. releases	0.0584	0.0662	0.0028	0.0252	0.0418
	(0.0314)*	(0.0846)	(0.0187)	(0.0321)	(0.0415)
N	224	222	225	216	223
# Countries	25	25	25	25	25
Avg yr.	9	8.9	9	8.6	8.9

Figure 9: Comparison of MV cassava area and cumulative releases

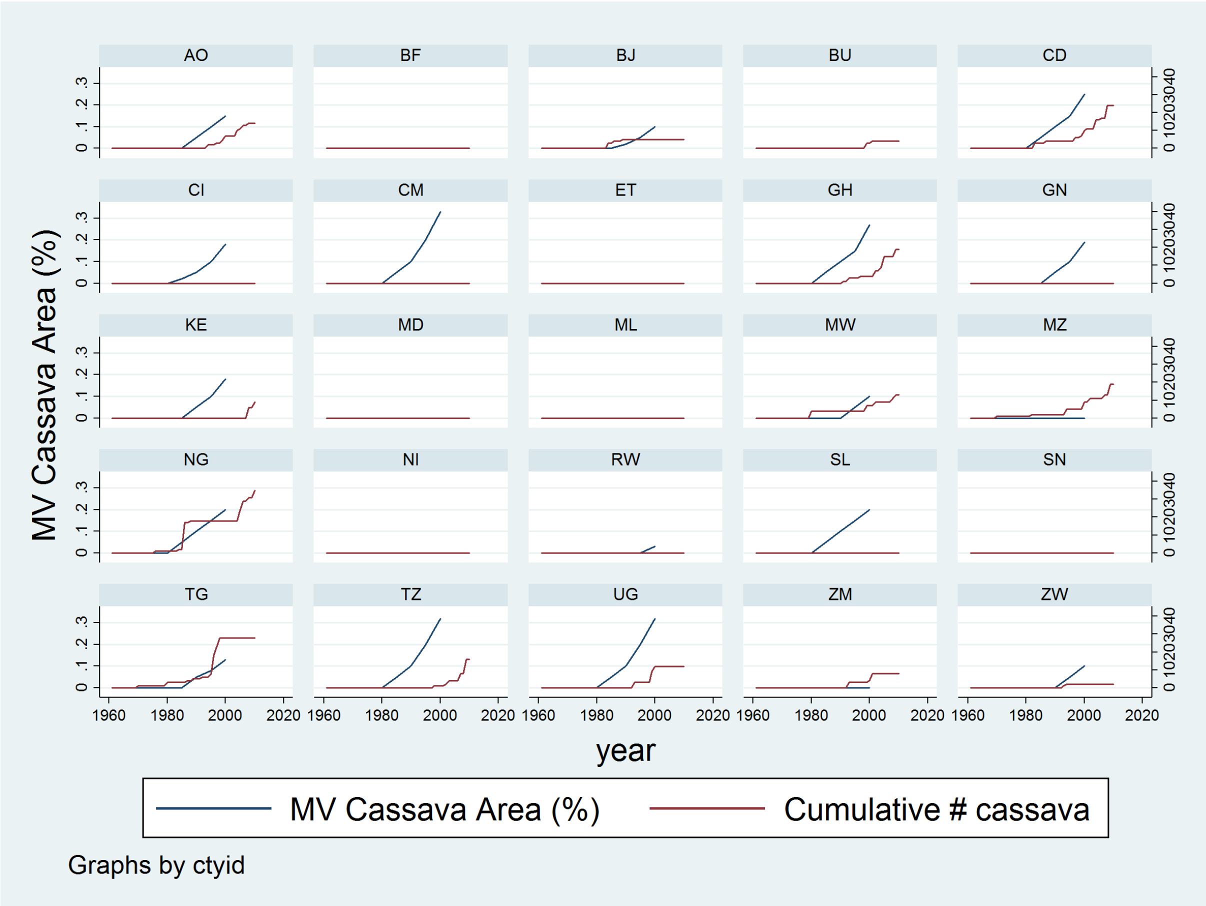


Figure 10: Comparison of MV maize area and cumulative releases

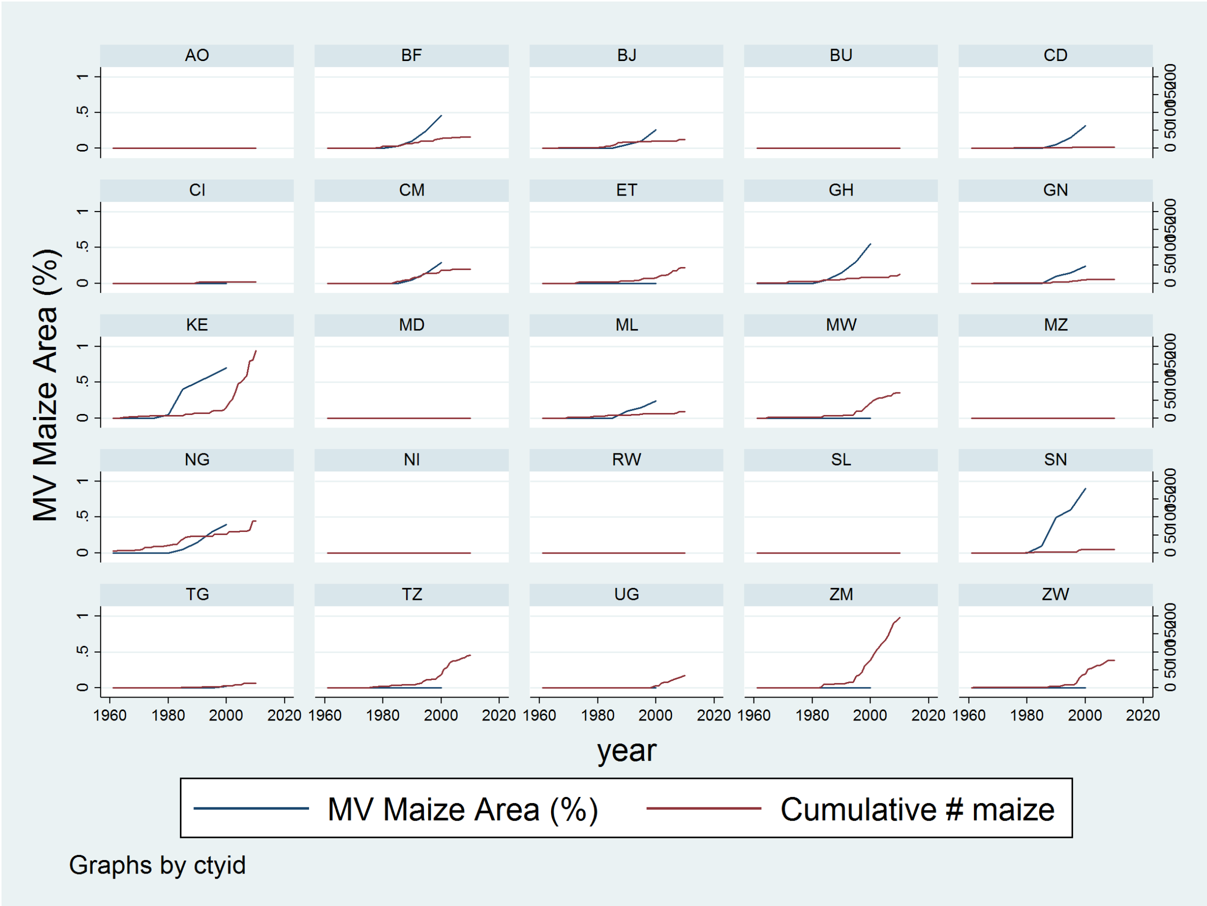


Figure 11: Comparison of MV rice area and cumulative releases

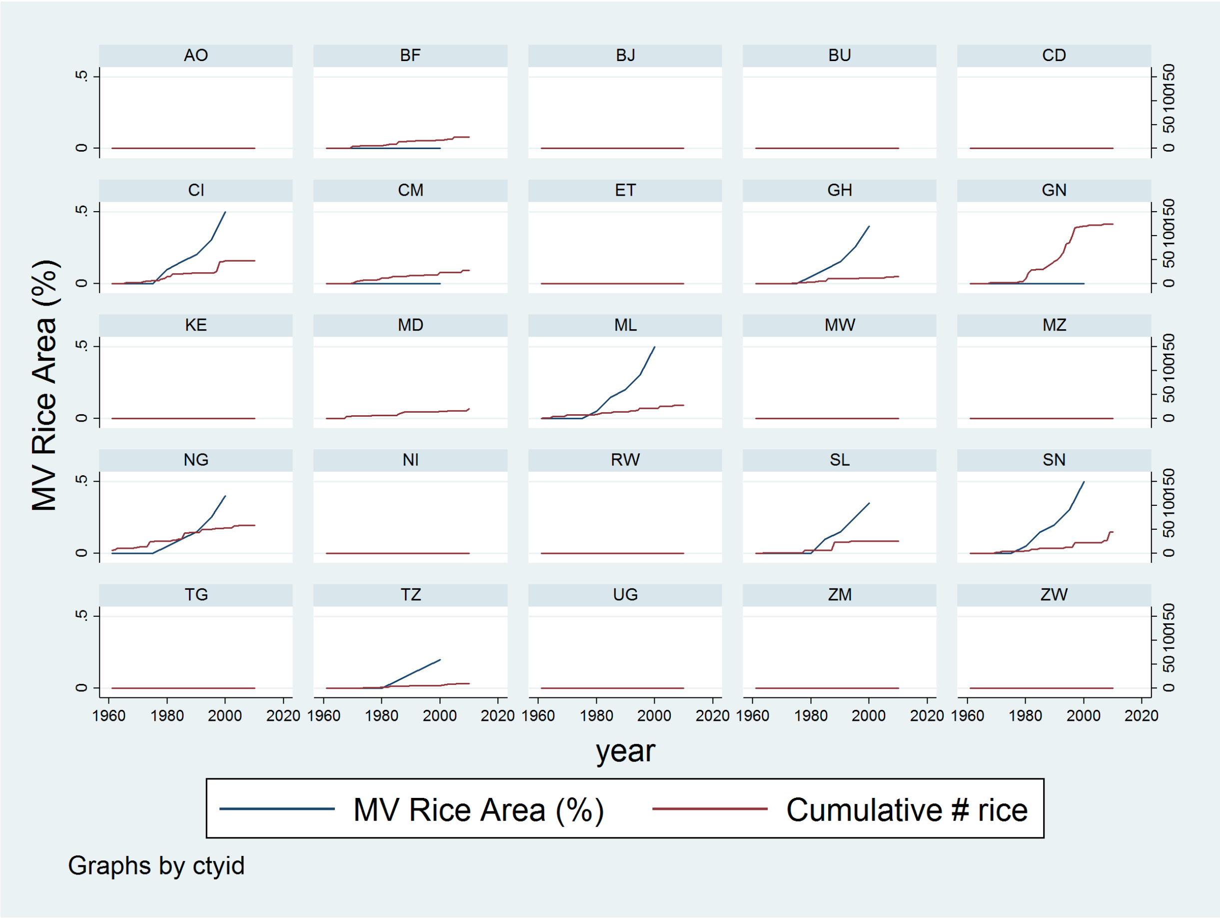
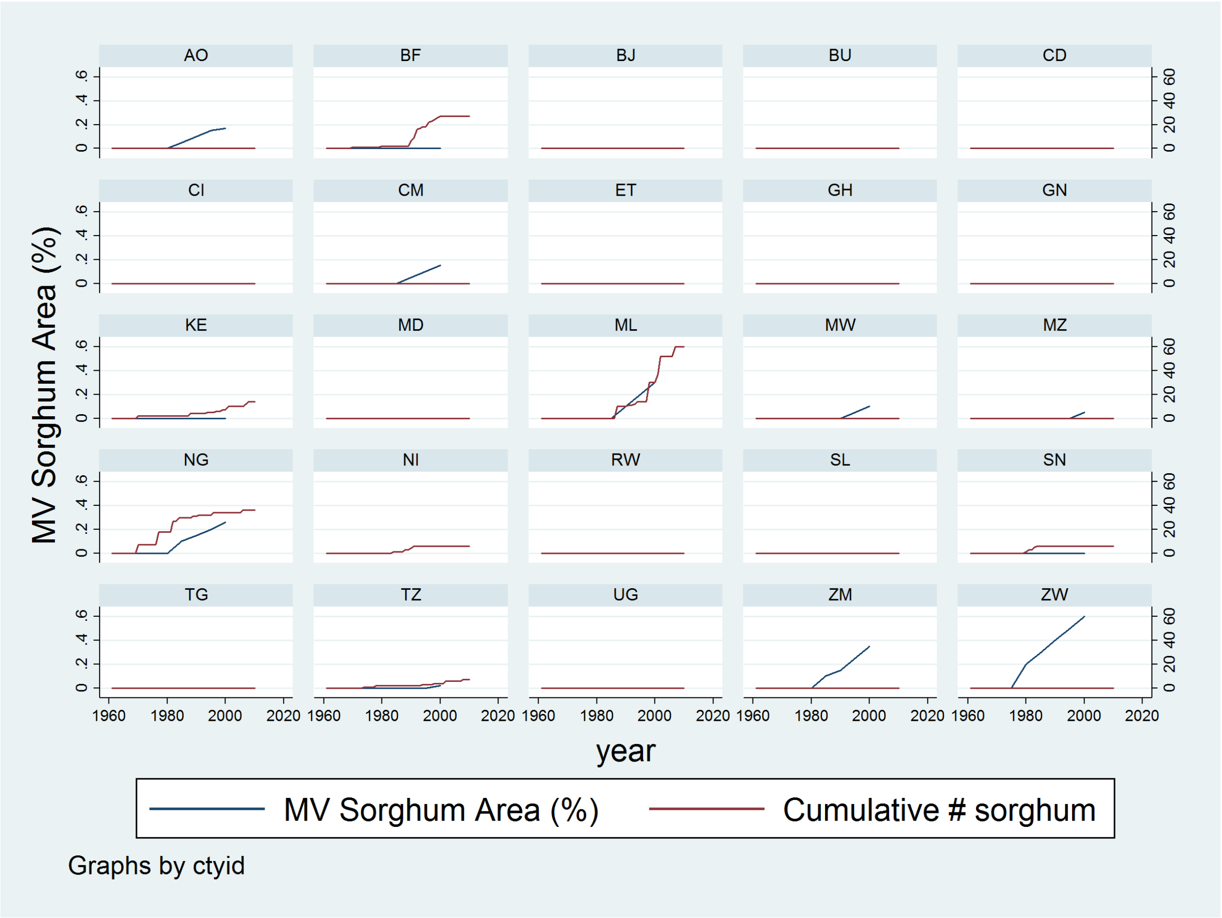


Figure 12: Comparison of MV sorghum area and cumulative releases



Trend break results

Table 9: Impact on MV areas and ln(yields) when cumulative releases > 0, 1961-2000

	(1) Cassava	(2) Maize	(3) Millet	(4) Rice	(5) Sorghum
Panel A: MV areas					
Post	−9.5996	−10.8284	−3.9547	−15.5707	−8.6806
	(2.4448)***	(3.9891)**	(3.5047)	(2.8369)***	(4.6789)*
Post × Trend	0.0049	0.0055	0.0020	0.0079	0.0044
	(0.0012)***	(0.0020)**	(0.0018)	(0.0014)***	(0.0024)*
N	234	234	234	234	234
Panel B: Yields					
Post	−1.6598	−6.9708	−6.5605	−6.9430	2.4027
	(12.4172)	(13.6409)	(6.9956)	(10.6562)	(12.4827)
Post × Trend	0.0008	0.0036	0.0033	0.0035	−0.0012
	(0.0062)	(0.0069)	(0.0035)	(0.0054)	(0.0063)
N	1,000	1,040	982	992	982

Note: Regressions control for country specific linear trends. Standard errors clustered at country level.

Global Agro-Ecological Zones

- Food and Agriculture Organization of the United Nations (FAO) and the International Institute for Applied Systems Analysis (IIASA) have developed an Agro-Ecological Zones (AEZ) methodology to assess agricultural resources and potential
- GAEZ provides data on agricultural suitability and potential yields for:
  - four input levels (high, intermediate, low and mixed)
  - five water supply system types (rain-fed, rain-fed with water conservation, gravity irrigation, sprinkler irrigation and drip irrigation)
  - at crop level (49 crops)
  - for baseline climate (1961-1990) and future climate conditions

Treatment Variable based on Potential Yields (from GAEZ)

For village v in country c at time t, define a measure:

- analogous to our original treatment variable (Equation 4)

$$MV \times PY(high)_{vct} = [\sum_{j}^{11}(PotentialYields(high)_{jvc} \times MVArea_{jct}]/11 \tag{6}$$

- of expected yields:

$$MV \times PY(expected)_{vct} = \sum_{j}^{11}[PY(high)_{jvc} \times MVArea_{jct} + PY(low)_{jvc} \times (1 - MVArea_{jct})]/11 \tag{7}$$

where, $PY(high)$ and $PY(low)$ refers to potential yields corresponding to high and low inputs respectively

Impact of MVs (using new measures from GAEZ)

Table 10: Reduced form impact of potential yields in 2000 x MV on infant mortality

	(1) All	(2) Girls	(3) Boys
MV $\times$ PY (exp)	0.0050	0.0230	-0.0144
	(0.0134)	(0.0157)	(0.0206)
N	636,542	309,685	325,365
MV $\times$ PY (high)	0.0042	0.0184	-0.0113
	(0.0107)	(0.0127)	(0.0164)
N	636,542	309,685	325,365

Country Case Study Options

- India: Data is available on district (admin level 2) level data on wide range of agricultural indicators from 1966 to 2009. DHS type data is not geo-referenced but potentially available at similar resolution.
- Ethiopia: compiled subnational data (admin level 1) on input use (MVs, irrigation, fertilizers and pesticides) from 1997 to 2010 (at 10 points of time) and plan to link it to LSMS-ISA and DHS
- Other suggestions?

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