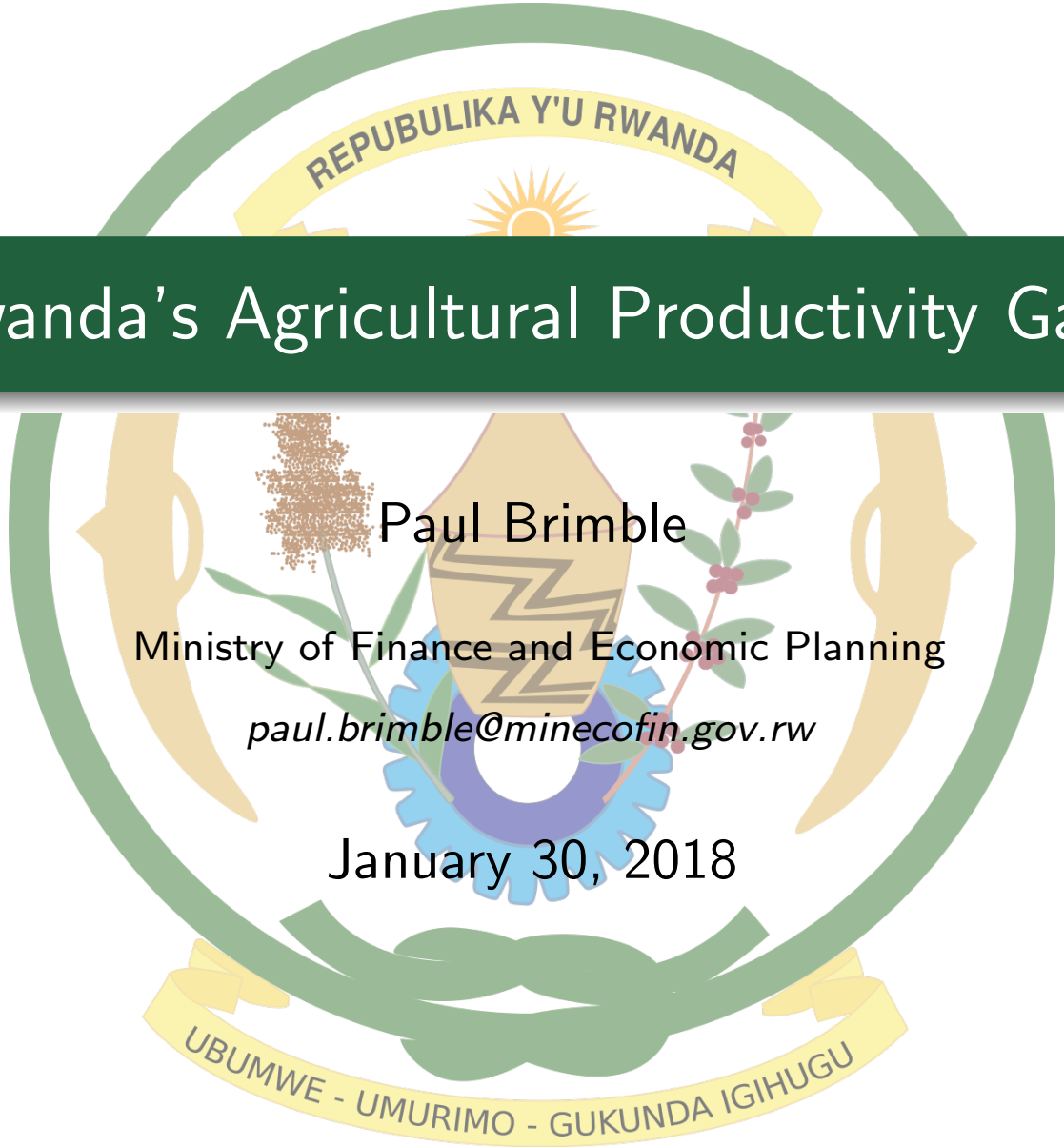

Rwanda's Agricultural Productivity Gaps

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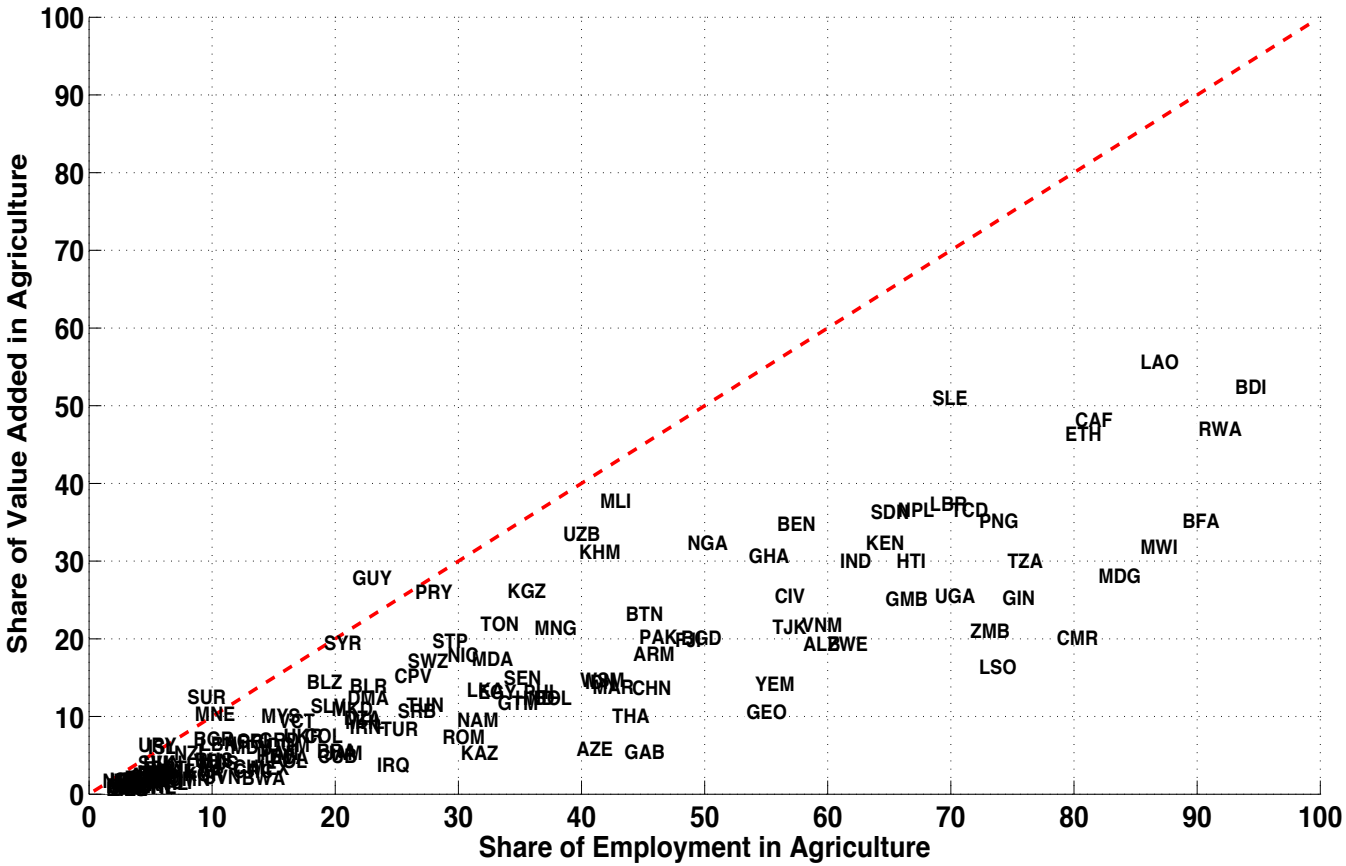
Overview

Agricultural Sector

- Agricultural productivity gaps persist throughout the world
- Share of value added is lower than the share of employment in the agricultural sector
- The gaps are largest amongst developing countries
- These gaps are highly correlated with income

Agricultural Sector Across Countries

Figure 1



Source: Gollin et al. (2014)

Agricultural Productivity Gaps Across Countries

- The mean raw agricultural productivity gap is 3.5
- The gap rises amongst the poorest countries
- The gaps are significantly large across many countries

Table 1

	All Countries	Quartile of Income Distribution			
		Q1	Q2	Q3	Q4
10th Percentile	1.3	1.0	1.3	1.0	1.2
Median	2.6	1.7	2.7	2.8	4.3
Mean	3.5	2.0	3.2	3.4	5.6
90th Percentile	6.8	4.0	6.6	7.1	12.5
Number of Countries	151	38	38	38	37

Source: Gollin et al. (2014)

Contributing Factors

1) Mismeasurement

2) Differences in hours worked per worker across sectors

3) Differences in human capital per worker across sectors

4) Misallocation of workers across sectors

Purpose of this Paper

- This paper addresses 3 contributing factors of the APGs:
  1) Construct more accurate measures for value added and labour employment shares
  2) Construct sectoral measures of hours worked per worker
  3) Construct sectoral measures of human capital per worker
- The adjusted agricultural productivity gap will only reflect the misallocation of labour
- Policy implication: encourage migration out of the agricultural sector

Neoclassical Theory Assumptions

- Two-sector economy: Agriculture (a) and Non-agriculture (n)
- Cobb-Douglas production function
- Constant returns to scale
- Equality of labour share in production (θ)

$$Y_a = A_a L_a^{\theta} K_a^{1-\theta} \qquad \text{and} \qquad Y_n = A_n L_n^{\theta} K_n^{1-\theta} \tag{1}$$

- Labour mobility
- Competitive labour markets
- Equality of hours worked and human capital across sectors

Equilibrium Predictions

- Labour mobility implies equalised equilibrium wage
- Competitive labour markets imply that workers are paid the value of their marginal products
- The equilibrium wage:

$$W_i = P_i MPL_i = \frac{\theta P_i Y_i}{L_i} = \frac{\theta V_i}{L_i} \qquad \text{for} \quad i = a, n \qquad (2)$$

- Equating the marginal value products gives the raw agricultural productivity gap:

$$\frac{\frac{V_n}{L_n}}{\frac{V_a}{L_a}} = 1 \qquad (3)$$

Efficiency Units of Labour Hours

- Adjust the production function to factor in hours worked (Hrs) and human capital (H)
- Introduce efficiency units of labour hours $E = L \cdot Hrs \cdot H$

$$Y_i = A_i E_i^{\theta} K_i^{1-\theta} \qquad \text{for} \quad i = a, n \tag{4}$$

- The adjusted agricultural productivity gap:
- Equating the marginal value products gives the raw agricultural productivity gap:

$$\frac{\frac{V_n}{E_n}}{\frac{V_a}{E_a}} = 1 \tag{5}$$

Raw and Adjusted Agricultural Productivity Gaps

- The agricultural productivity gaps can be expressed using value added shares (v) and labour employment shares (l)
- The raw agricultural productivity gap:

$$\frac{\frac{(1-v_a)}{(1-l_a)}}{\frac{v_a}{l_a}} = 1 \tag{6}$$

- The adjusted agricultural productivity gap:

$$\frac{\frac{(1-v_a)}{(1-l_a)}}{\frac{v_a}{l_a}} \div \left(\frac{Hrs_n}{Hrs_a}\right) \div \left(\frac{H_n}{H_a}\right) = 1 \tag{7}$$

Raw Agricultural Productivity Gaps

- The raw agricultural productivity gaps are computed using only value added and labour employment shares
- Distinguish between the raw macro APGs and raw micro APGs
- Raw macro APGs are computed using macro data (national accounts)
- Raw micro APGs are computed using micro data (household surveys)

Raw Macro Agricultural Productivity Gaps

- The macro data comes from two sources:

1) Measures for value added shares (v_a and v_n)
   - Source: UN National Account Statistics

2) Measures for labour employment shares (l_a and l_n)
   - Source: ILO Modelled Estimates

Estimates of Raw Macro Agricultural Productivity Gaps

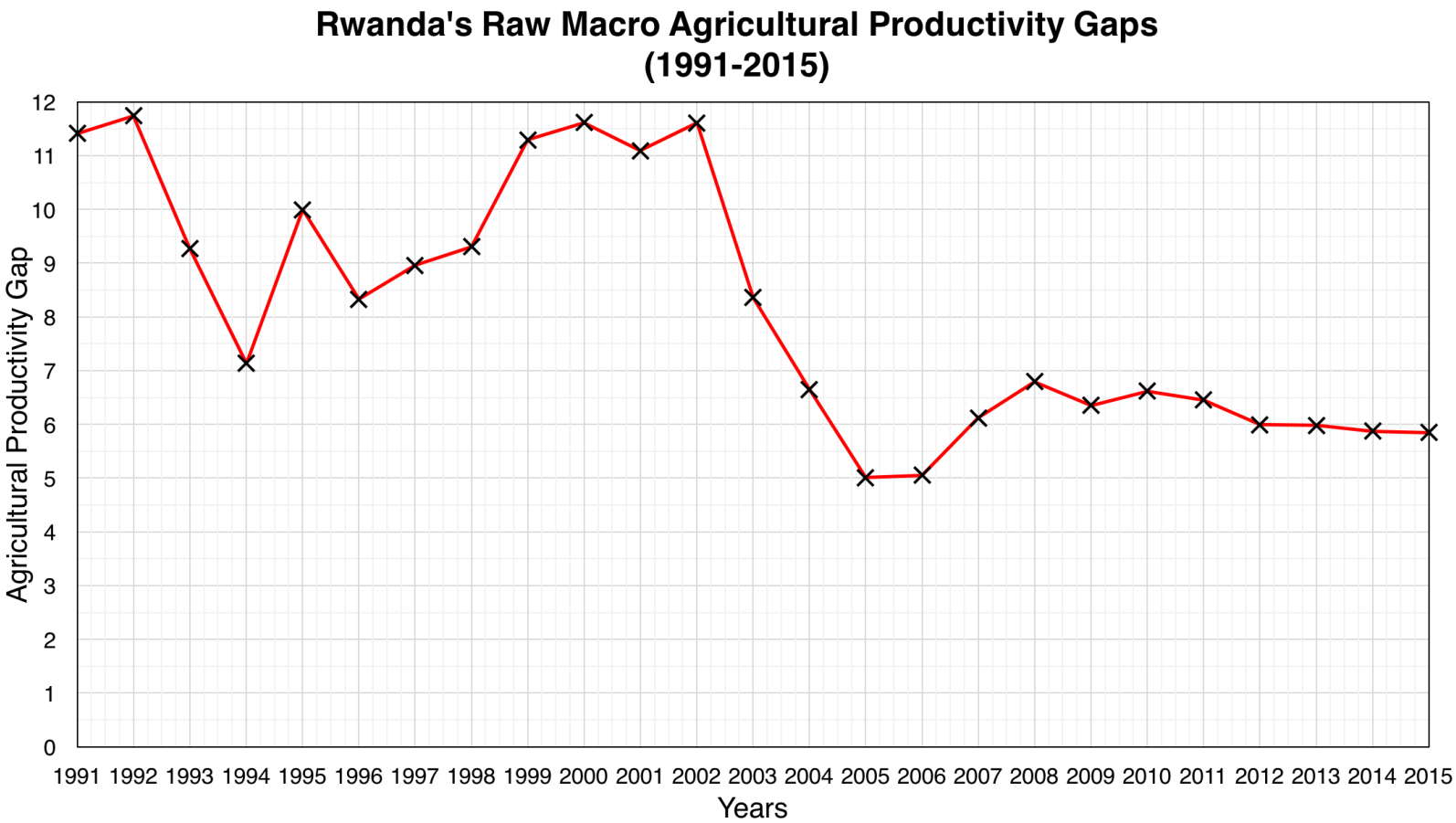
Table 2

Macro Agricultural Productivity Gaps			
Year	**Labour Employment Shares**	**Value Added Shares**	**Raw APG**
1991	88.0	39.12	11.41
1995	88.9	44.50	9.99
2000	88.2	39.16	11.61
2005	77.9	41.30	5.01
2011	77.4	34.66	6.46
2014	76.0	35.02	5.88

Source: UN National Accounts and ILO Estimates

Historical Trends in Raw Macro APGs

Figure 2



Source: UN National Accounts and ILO Estimates

Key Results from Raw Macro APGs

- Rwanda has large raw macro APGs
- Significant improvements during the early 2000s
- Relatively stable over the past decade

Raw Micro Agricultural Productivity Gaps

- Mismeasurement of value added and labour employment shares from macro data can be addressed using micro data
- Agricultural value added may be underestimated due to home production, leading to an overestimation of the APG
- A large proportion of the economically active population consists of self employed and contributing family workers which can bias the labour employment shares
- Informality and household production also bias estimates
- The micro data comes the Integrated Household Living Conditions Survey:
  - EICV2 (2006)
  - EICV3 (2011)
  - EICV4 (2014)

Computing Micro Estimates

- The micro estimates are computed at 3 levels of aggregation:
  - Job level (indexed by j)
  - Worker level (indeed by i)
  - Household level (indexed by h)
- The sectors are indexed by $s = \{a, n\}$
- Main outcomes:
  - Labour income: Y^L
  - Self-employed income: Y^{SE}
  - Hours worked: Hrs
  - Years of schooling and literacy: edu and lit
  - Capital income per household: Y^K
  - Value added per household: V

Computing Micro Estimates (Job Level)

- Jobs are defined for all wage earners, self-employed income earners and unpaid family workers
- Income is allocated to unpaid family workers based on their hours worked
- Each job has the following information:
  - Sector classification: $s = \{a, n\}$
  - Labour income: $Y^{L}_{s,hij}$
  - Self-employed income: $Y^{SE}_{s,hij}$
  - Hours worked: $Hrs_{s,hij}$

Computing Micro Estimates (Worker Level)

- Each worker has the following information:
  - Main job classified by i) hours worked and if tie, by ii) income
  - Sector classification by main job sector: $s = \{a, n\}$
  - Labour income: $Y^L_{s,hi} = \sum_j Y^L_{a,hij} + \sum_{-j} Y^L_{n,hij}$
  - Self employed income: $Y^{SE}_{s,hi} = \sum_j Y^{SE}_{a,hij} + \sum_j Y^{SE}_{n,hij}$
  - Hours worked: $Hrs_{s,hi} = \sum_j Hrs_{a,hij} + \sum_j Hrs_{n,hij}$
  - Years of primary schooling: edu^1_{hi}
  - Years of secondary schooling: edu^2_{hi}
  - Years of tertiary schooling: edu^3_{hi}
  - Literacy: lit_{hi}

Computing Micro Estimates (Household Level)

- Each household has the following information:
  - Sector classification by i) majority of household workers and if tie, by ii) income: $s = \{a, n\}$
  - Labour income: $Y^L_{s,h} = \sum_i Y^L_{a,hi} + \sum_i Y^L_{n,hi})$
  - Self-employed income: $Y^{SE}_{s,h} = \sum_i Y^{SE}_{a,hi} + \sum_i Y^{SE}_{n,hi}$
  - Capital income: $Y^K_{s,h}$
  - Value added: $V_{s,h} = Y^L_{s,h} + Y^{SE}_{s,h} + Y^K_{s,h}$
  - Hours worked: $Hrs_{s,h} = \sum_i Hrs_{a,hi} + \sum_i Hrs_{n,hi}$

Computing Raw Micro Agricultural Productivity Gaps

- Labour employment shares are calculated at the worker level
- Value added shares are calculated at the household level
- These shares are calculated by applying the survey weights

Estimates of Raw Micro Agricultural Productivity Gaps

Table 3

Micro Agricultural Productivity Gaps			
Year	**Labour Employment Shares**	**Value Added Shares**	**Raw APG**
2006	76.93	45.92	3.93
2011	70.32	30.82	5.32
2014	67.75	31.83	4.50

Source: EICV2, EICV3 and EICV4

Robustness Measures for Value Added

- Workers are classified by the sector of their main job
- Households are classified by the sector of the majority of household workers
- Labour and self employed income from sector s may be misattributed to the other sector t at both the worker and household level
- Example: If an agricultural worker earns income from non-agricultural work, this would overestimate agricultural income
- This bias is only quantitatively important if a substantial share of worker income is misallocated in this way

Robustness Measures for Value Added (Worker Level)

Table 4

Mean Annual Labour and Self Employed Income			
		Sector of Income	
Year	**Worker Classification**	Agriculture	Non-Agriculture
2006	Agriculture	99,028	4,493
	Non-Agriculture	20,565	301,504
2011	Agriculture	194,739	33,346
	Non-Agriculture	74,550	1,005,422
2014	Agriculture	295,058	33,984
	Non-Agriculture	39,344	1,316,164

Source: EICV2, EICV3 and EICV4

Robustness Measures for Value Added (Household Level)

Table 5

Mean Annual Labour and Self Employed Income			
		Sector of Income	
Year	**Household Classification**	Agriculture	Non-Agriculture
2006	Agriculture	205,151	1,684
	Non-Agriculture	84,839	646,322
2011	Agriculture	424,403	68,823
	Non-Agriculture	224,900	2,086,121
2014	Agriculture	605,464	83,804
	Non-Agriculture	165,318	2,446,288

Source: EICV2, EICV3 and EICV4

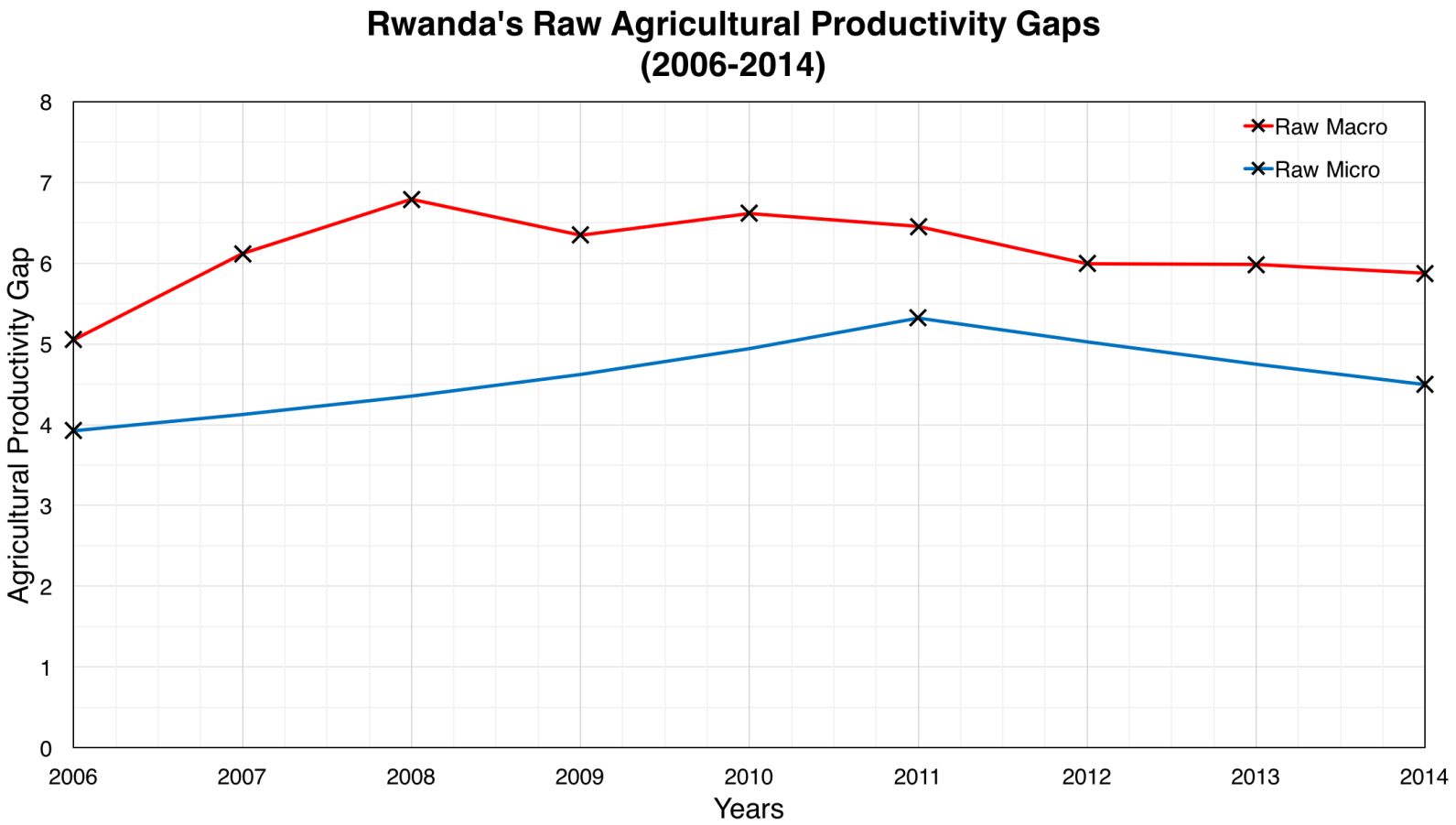
Comparing Raw Macro and Micro APGs

Raw Agricultural Productivity Gaps						
Year	**Labour Employment Shares**		**Value Added Shares**		**Raw APG**	
	Macro	**Micro**	**Macro**	**Micro**	**Macro**	**Micro**
2006	78.4	76.93	39.80	45.92	5.05	3.93
2011	77.4	70.32	34.66	30.82	6.46	5.32
2014	76.0	67.75	35.02	31.83	5.88	4.50

Source: UN National Accounts, ILO Estimates, EICV2, EICV3 and EICV4

Recent Trends in Raw Macro and Micro APGs

Figure 3



Source: UN National Accounts, ILO Estimates, EICV2, EICV3 and EICV4

Key Results from Raw Micro APGs

- The raw micro agricultural productivity gap addresses the mismeasurement issue by:
  - Including more home consumption into agricultural output
  - Including more unpaid family workers
  - Including more of the informal sector
  - Excluding the value added from large multinational organisations

- The raw agricultural productivity gap is approximately reduced by a factor of 1.2

Adjustments Outline

- Two adjustments are required to convert the raw APGs to the adjusted APGs:
  1) Hours worked per worker across sectors (quantity adjustments)
  2) Human capital across sectors (quality adjustments)

- Use Integrated Household Living Conditions Survey:
  - EICV2 (2005)
  - EICV3 (2011)
  - EICV4 (2014)

Estimates of Hours Worked

- Hours worked are calculated for each job in annual hours
- These hours are then aggregated to the worker level

Table 7

Mean Annual Hours Worked						
	2006		2011		2014	
Worker Classification	Hours	Ratio	Hours	Ratio	Hours	Ratio
Non-Agriculture	2,186	1.93	2,841	1.82	2,002	1.89
Agriculture	1,134		1,565		1,061	

Source: EICV2, EICV3 and EICV4

Robustness Measures for Hours Worked (Seasonality)

- Agricultural work can be highly seasonal which may affect the hours worked statistics
- If the household survey systematically interviews agricultural workers in or out of harvest periods, this could bias the average hours worked
- Seasonality is addressed by calculating annual hours which are robust to seasonal fluctuations

Robustness Measures for Hours Worked (Secondary Jobs)

- Workers are classified by the sector of their main job
- Workers may have multiple jobs from different sectors
- All the hours worked from these jobs are classified under the main job sector
- Hours from sector s may be misattributed to the other sector t
- Example: If an agricultural worker devotes a share of their hours worked to non-agricultural work, this would overestimate agricultural hours worked
- This bias is only quantitatively important if a substantial share of hours worked are misallocated in this way

Robustness Measures for Hours Worked (Secondary Jobs)

Table 8

Mean Annual Hours Worked			
		Sector of Hours Worked	
Year	**Worker Classification**	Agriculture	Non-Agriculture
2006	Agriculture	1,105	29
	Non-Agriculture	134	2,052
2011	Agriculture	1,454	111
	Non-Agriculture	422	2,419
2014	Agriculture	1,021	40
	Non-Agriculture	84	1,918

Source: EICV2, EICV3 and EICV4

Human Capital

- Human capital for worker i is a function of average returns to schooling ($\bar{r}$) and years of schooling ($edu_{s,hi}$)
- Years of schooling differ significantly between agricultural and non-agricultural workers

Table 9

Years of Schooling						
	2006		2011		2014	
Worker Classification	Mean	Median	Mean	Median	Mean	Median
Non-Agriculture	4.87	5	5.55	5	5.80	6
Agriculture	2.82	3	3.08	3	3.45	4

Source: EICV2, EICV3 and EICV4

Human Capital Functional Form

- The functional form for a worker's human capital is:

$$H_{s,hi} = \exp(\bar{r} \cdot edu_{s,hi}) \tag{8}$$

- The sectoral stock of human capital for sector s is calculated by using the mean years of schooling amongst sector s workers $\overline{edu_s}$:

$$H_s = \exp(\bar{r} \cdot \overline{edu_s}) \tag{9}$$

Improved Measures of Human Capital

- Returns to education differ across 3 dimensions:
  1. Returns differ across time
  2. Returns differ across education level: primary (r^1), secondary (r^2) and tertiary (r^3)
  3. Returns differ across sectors: agricultural (r_a) and non-agricultural (r_n)

- Return to education come from the World Bank:
  - Comparable Estimates of Returns to Schooling Around the World (2014)

Table 10

Returns to Education				
Year	**Average**	**Primary**	**Secondary**	**Tertiary**
2005	17.5	16.9	17.8	35.3
2010	22.4	34.1	19.7	28.8

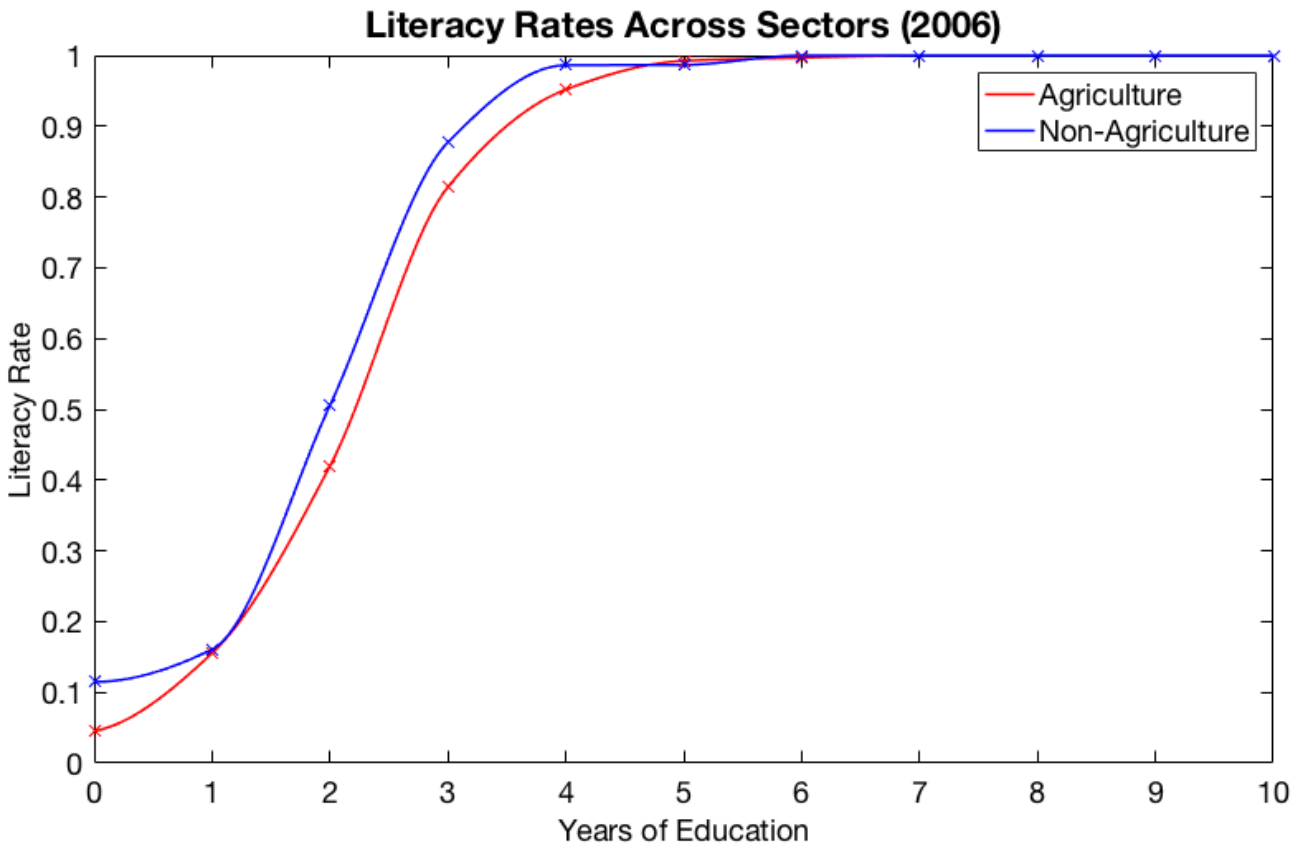
Source: World Bank (2014)

Returns to Education Across Sectors

- Quality of schooling differs across sectors
  - Differences in nutrition and health lead to missed school and lower absorption during school
  - Differences in parental inputs and education resources
- Differences in returns to education across sectors is calculated by comparing literacy rates
  - Literacy rates are higher for non-agricultural workers for almost all years of schooling
  - These literacy differences can be used to determine differential returns to education

Literacy Rate Differences (2006)

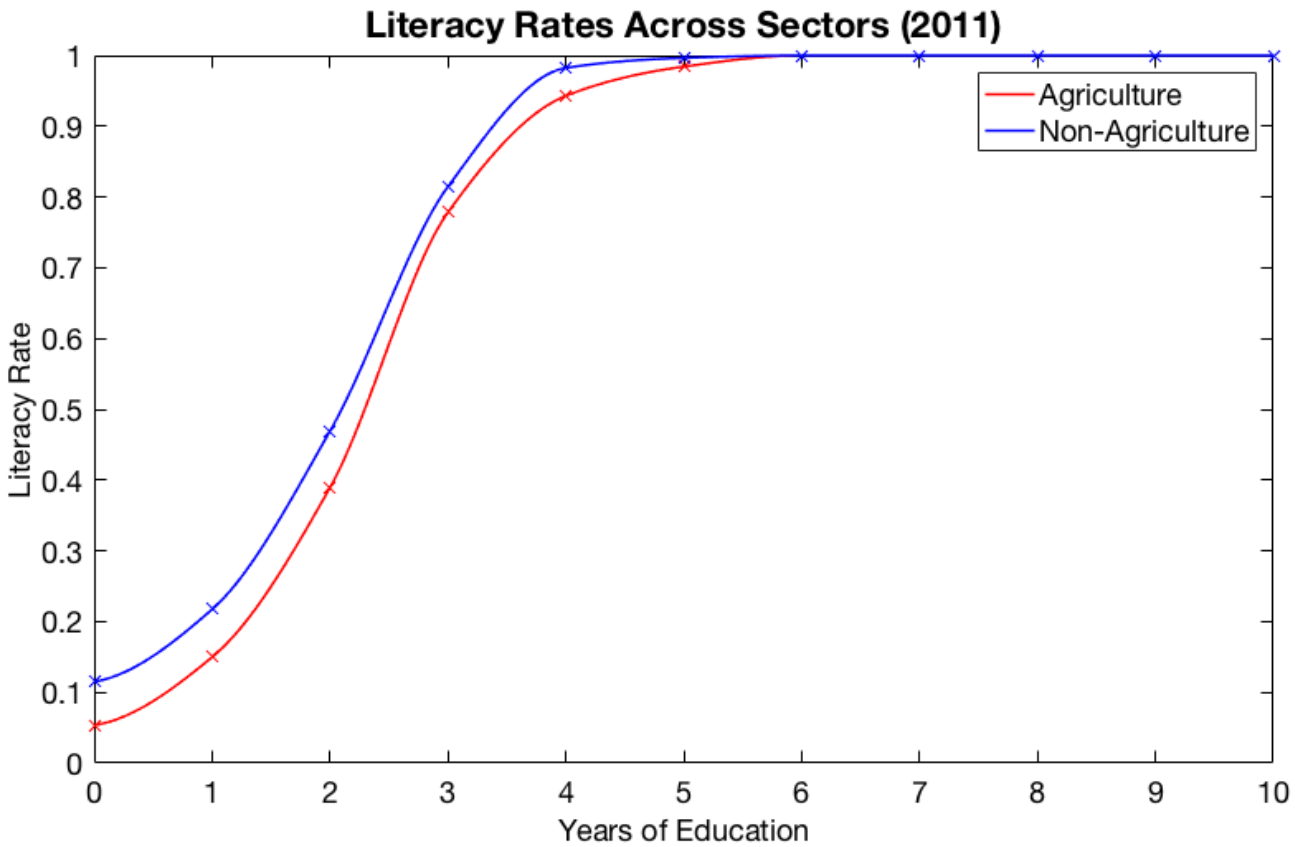
Figure 4



Source: EICV2

Literacy Rate Differences (2011)

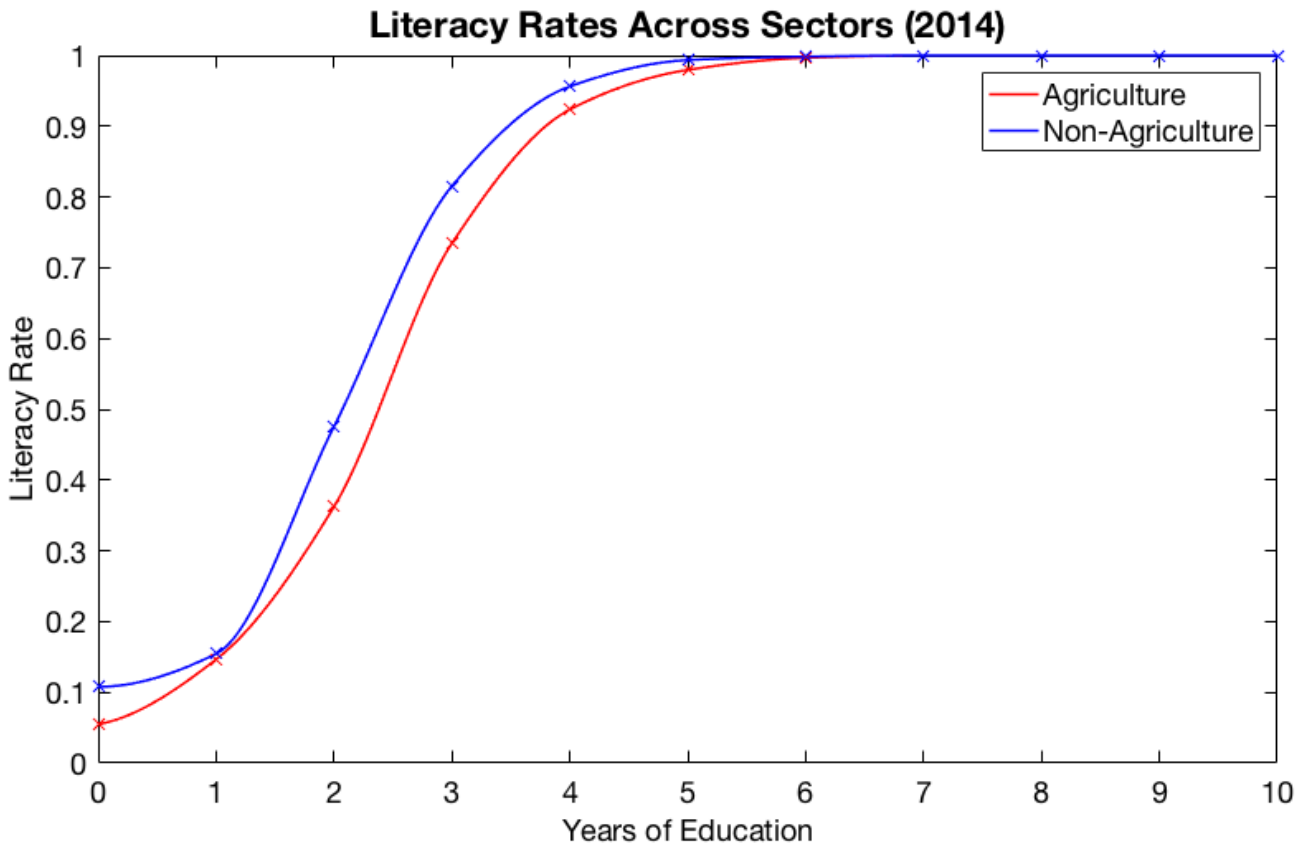
Figure 5



Source: EICV3

Literacy Rate Differences (2014)

Figure 6



Source: EICV4

Literacy Adjusted Returns to Education

- Use literacy rates to adjust the sectoral returns to education
- Define $lit_s(edu)$ as the literacy rate for given years of schooling (edu) in sector s
- Interpolate the data and create a continuous literacy rate function: $\widetilde{lit}_s(edu)$ for each sector s
- Posit that edu years of agricultural education is as effective as $\gamma \cdot edu$ years of non-agricultural education
- γ is set to the value which solves:

$$\min_{\gamma} \sum_{edu=1}^{\overline{edu}} \left(\widetilde{lit}_n(\gamma \cdot edu) - \widetilde{lit}_a(edu) \right)^2 \tag{10}$$

- Estimates for γ: **0.91** (2005), **0.92** (2011) and **0.89** (2014)

Estimates of Human Capital

- Incorporate all 3 dimensions of returns to education
- The sectoral stock of human capital for a given year is:

$$H_n = \exp\left(r^1 \cdot \overline{edu_n^1} + r^2 \cdot \overline{edu_n^2} + r^3 \cdot \overline{edu_n^3}\right) \tag{11}$$

$$H_a = \exp\left(\gamma\left\{r^1 \cdot \overline{edu_a^1} + r^2 \cdot \overline{edu_a^2} + r^3 \cdot \overline{edu_a^3}\right\}\right) \tag{12}$$

- The values for $\overline{edu_s^x}$ are calculated by dividing up $\overline{edu_s}$

Table 11

Sectoral Human Capital Stock						
	2006		2011		2014	
Worker Classification	H_s	Ratio	H_s	Ratio	H_s	Ratio
Non-Agriculture	2.21	1.46	2.99	1.71	3.14	1.71
Agriculture	1.52		1.75		1.83	

Source: EICV2, EICV3 and EICV4

Adjusted Agricultural Productivity Gaps

- Procedure for calculating the adjusted APG:
  - Calculate the raw APG
  - Apply adjustments (hours worked and human capital)
  - Outcome is the adjusted APGs

- The micro adjusted APG will account for:
  1. Mismeasurement
  2. Differences in hours worked
  3. Differences in human capital

Estimates of Adjusted Agricultural Productivity Gaps

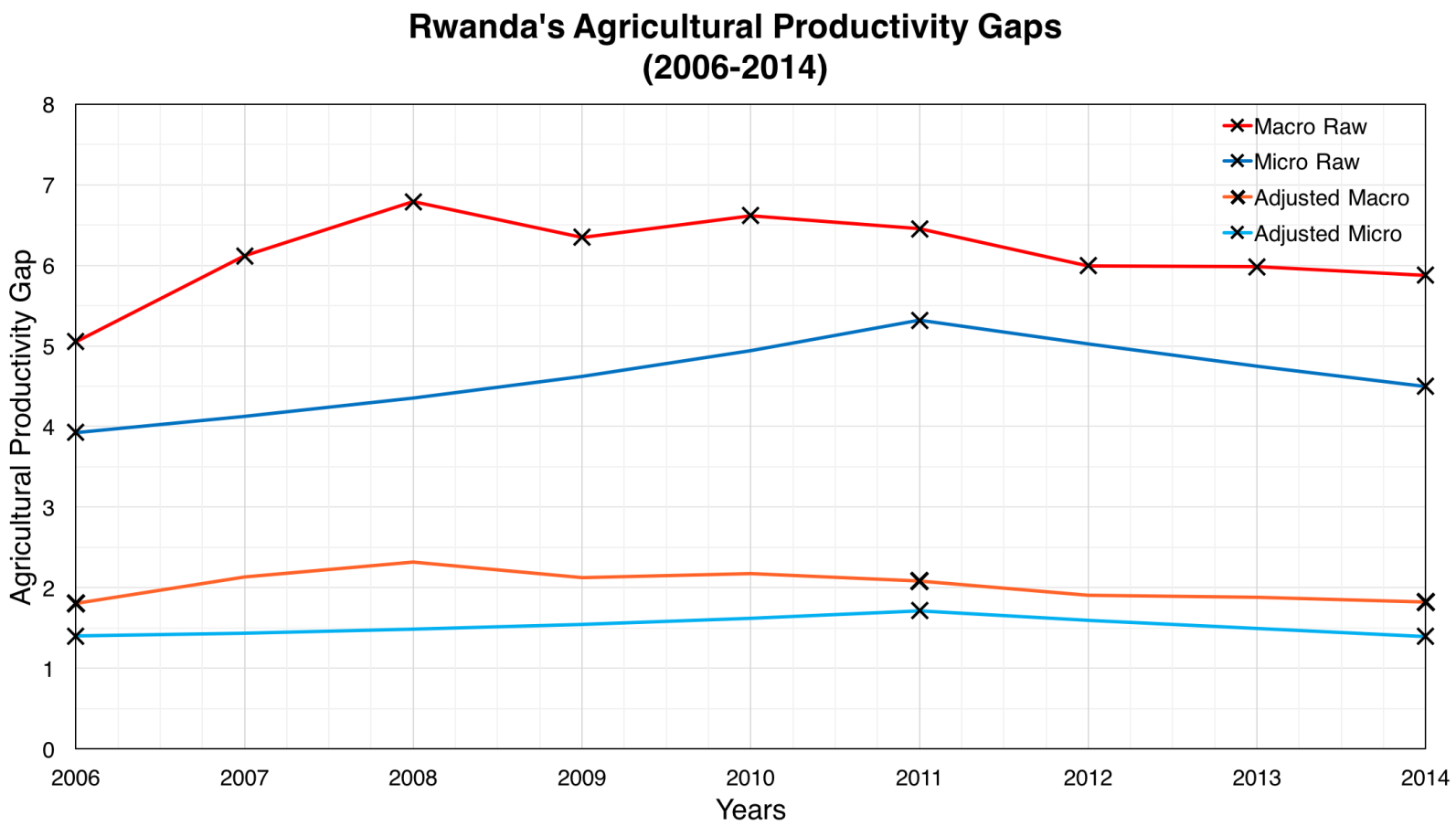
Table 12

Comparison of Raw and Adjusted Agricultural Productivity Gaps						
	Raw APG		Adjustments		Adjusted APG	
Year	Macro	Micro	$\frac{Hrs_n}{Hrs_a}$	$\frac{H_n}{H_a}$	Macro	Micro
2006	5.05	3.93	1.93	1.46	1.80	1.40
2011	6.46	5.32	1.82	1.71	2.08	1.71
2014	5.88	4.50	1.89	1.71	1.82	1.39

Source: UN National Accounts, ILO Estimates, EICV2, EICV3 and EICV4

Recent Trends in Agricultural Productivity Gaps

Figure 8



Source: UN National Accounts, ILO Estimates, EICV2, EICV3 and EICV4

Key Results from Adjusted APGs

- The micro adjusted APGs are approximately 1.5
- After addressing 1) mismeasurement, 2) hours worked and 3) human capital, there remains a sizeable agricultural productivity gap
- The gaps have been very stable over the past decade
- Closing the gap allows for welfare gains at a relatively low cost

Further Research

- Further research can be divided into two sections:

  1) Additional factors contributing to the APG

  2) Frictions causing the misallocation of labour between sectors

Improved Measures of Human Capital

- There are additional factors determining human capital such as experience and training
- Incorporating these factors into measures for human capital may affect the APG

Labour Shares of Production

- Suppose that the labour shares of production are different across sectors
- The Cobb-Douglas production functions can be modified:

$$Y_a = A_a E_a^{\theta_a} K_a^{1-\theta_a} \qquad \text{and} \qquad Y_n = A_n E_n^{\theta_n} K_n^{1-\theta_n} \tag{13}$$

- The adjusted agricultural productivity gap then becomes :

$$\frac{\frac{V_n}{E_n}}{\frac{V_a}{E_a}} = \frac{\theta_a}{\theta_n} \tag{14}$$

- Differences in the labour shares can potentially explain the adjusted agricultural productivity gap

Costs of Living and Real Incomes

- Costs of living may be a factor contributing to the productivity gap
- Increases in nominal incomes in the non-agricultural sector may be accompanied with increases in costs of livings
- Therefore, there may not be an increase in real incomes

Self Selection

- Workers self select into the agricultural and non-agricultural sector in such a way that produces an efficient agricultural productivity gap
- This gap is generated with no labour frictions
- The result is driven through heterogenous workers with differences in the distribution of ability
- The distribution of non-agricultural abilities is more dispersed than the distribution of agricultural abilities

Financial and Community Networks

- Community social and financial networks may prevent migration
- Informal social insurance and financial services are provided through small community networks (tontines, cooperations etc.)
- These benefits may be reduced after migration

Panel Analysis

- Panel data can be used to analyse worker productivity changes over time
- Econometric analysis can exploit productivity changes for stayers and switchers to determine the impact of sector choice on labour productivity
- Panel methods can eliminate endogeneity issues by removing innate ability (and other fixed effects)

Urban and Rural Inequality

- There are strong parallels between the agricultural/non-agricultural gap and the rural/urban gap
- Analysis of rural consumption gaps and wage gaps
- Analysis of rural urban inequality differences