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Modelling the Economy-Wide Impact of Technological Innovation and Mapping Agricultural Potential: The case of Burkina Faso

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Abstract

In this study, we develop an economy wide model for Burkina Faso to assess the most promising opportunities for technological innovations to enhance maize production and productivity and their economywide effects. We simulate the implementation of two agricultural technological innovations using a customized Computable General Equilibrium (CGE) model. One innovation is an improvement of famers' efficiency, i.e. operating on the production frontier (typology scenario). The other shifts the frontier itself and involves the introduction of a new cultivar (crop scenario). The model has been made agriculture-focused through the following features: separate agriculture and non-agriculture labor markets, separate urban and rural representative household groups, including welfare analysis and the imperfect integration of land markets, i.e. the land market is split into agroecological zones (AEZs). The CGE model is a single-country, multi-sector, multi-market model and solved for multiple periods in a recursive manner, ten years in the case of Burkina Faso. The CGE model is calibrated using a 2013 Social Accounting Matrix (SAM). The SAM has several interesting features with regards to agricultural modelling and highlights the focus crops for Burkina Faso and particularly maize, which is the focus crop of this study. The results showed prospects of gains for the economy with the introduction of technological innovations in the maize value chain in Burkina Faso. Welfare analyses performed showed welfare gains for all household profiles studied. In other words, the introduction of innovations in the maize value chain seems to be pro-poor. Finally, the study found that a total increase of about 2% of public expenditure in this sector over 10 years is required to achieve the simulated results.

Keywords: agricultural innovation; productivity growth; CGE modelling

JEL codes: C68; Q16; Q18

1. Introduction

The agricultural sector is an essential component of Burkina Faso's economy. It contributes 35% to the Gross Domestic Product (GDP) of the country and employs 82% of the active population. Agricultural production is dominated by cereals (sorghum, millet, maize and rice), cotton and livestock. Arboriculture and market gardening also play a significant role. Burkina Faso, like other countries in the Sahel, is not food self-sufficient. Cereals constitute a large part of the diet of the population. Maize cultivation is booming in the country especially in the cotton zones where maize is integrated in the production system and can benefit from the inputs (fertilizer) used in cotton production. In 1985, only 9% of produced cereals were maize while in 2015 the share of maize in total cereal production was around 23%. Maize is of paramount importance during the lean season and is grown throughout the country.

Despite the progress made in recent years, the agricultural sector in Burkina Faso suffers from low productivity due to several unfavorable factors: climatic hazards, declining soil fertility, weak infrastructure - especially roads - lack of organization of sectors (excluding cotton), low investment and insufficient training of human resources. The major challenge of the rural sector for the coming years is to ensure food and nutrition security for an increasingly growing population in the context of climate change. The country's 2016-2025 Rural Development Strategy (SDR) envisages the agricultural sector as modern, competitive, sustainable and the engine of economic growth, based on family farms and efficient agricultural enterprises. The strategy also sets out to ensure that all Burkinabe have access to the food necessary for a healthy and active life. The overall goal of the SDR is to ensure sustainable food and nutrition security, contribute to economic growth, improve living conditions and reduce people's vulnerability to climatic and economic hazards. The first strategic objective of the SDR is to sustainably increase agricultural production and productivity.

Globally, the production of cereals has increased dramatically during the past 50 years. This is partly due to the extension of crop growing areas and the development of new varieties but mainly because of intensified land management and introduction of new technologies (Neumann et al., 2010). However, according to FAO, the yield of six major cereal crops including maize, wheat, millet, sorghum, rice, and barley in Africa is consistently less than 50% of the global yield. The global crop yield variability is largely determined by fertilizer application, irrigation and climate (Mueller et al., 2013). Nutrient limitations are the major yield limiting factor of maize productivity in West Africa (FAO, 2014). Technological innovations that improve agricultural potential could thus play an important role. However, it also needs to be noted that due to spatial heterogeneity, technological innovations that lead to increased fertilizer application may have different income and welfare improvements across the country. Also, technological innovations could be of a smaller magnitude, for example interventions that allow smallholders to catch up to their peers and larger farmers by helping them overcome the specific challenges they face.

The implementation of the first strategic orientation of the SDR, which is to sustainably intensify cereal production envisages the facilitation of access to agricultural inputs and the dissemination of technology packages based on sound research. In this study, we develop an economy wide model for Burkina Faso to assess the most promising opportunities for technological innovations to enhance maize production and productivity and their economywide effects. We simulate the implementation of two technological innovations using a customized Computable General Equilibrium (CGE) model. One innovation is an improvement of famers' efficiency, i.e. operating on the production frontier. The other shifts the frontier itself and involves the introduction of a new cultivar. The model is designed at the subnational level to reflect agroecological zones. Working at the subnational level allows us to consider different types of land and climatic conditions. The latter are associated with specific technologies and productivity levels.

The study continues as follows: the next section provides a background to the study and describes Burkina Faso's agricultural sector. Section three includes a detailed description of the model and describes the data used to calibrate the model. Section four describes the scenarios that were simulated. In section 5 results of the simulations are discussed. We conclude in Section 6.

2. Agricultural practices in Burkina Faso with a focus on maize

Agricultural production in Burkina Faso is dominated by cereals such as sorghum, millet, maize and, to a lesser extent, rice. Cultivation is largely rainfed and there is only one short cropping season a year. Using province level data, the country can be divided into five agroecological zones based on length of growing periods (Figure 1). Some similarities and differences between these five AEZs in terms of agricultural production systems and rainfall are observed. Using additional data from IFPRI eAtlas in 2015[1], AEZ1 is characterized by an annual rainfall level of between 330 and 552 mm. In terms of agricultural production systems, food crop-producing systems (millet, sorghum, cowpeas) are more common in this zone. Rainfall levels for AEZ2 are between 553 and 693 mm. In this zone, the same crops as in AEZ1 are cultivated. Regarding the cotton basin - represented by AEZ3 - it is noted that annual rainfall ranged from 697 to 913 mm. For this zone, we observe more cotton and maize cropping in addition to food crops. The annual rainfall level for AEZ4 is between 697 and 1380 mm. The cropping patterns are similar to those in AEZ3. Finally, the rainfall level in AEZ5 is between 914 and 1380 mm. The agricultural production systems are more diversified in this zone compared to the other zones because these include perennial crops like mango, citrus, cashew, in addition to cereals (millet, sorghum, maize) and roots and tubers.

The cereal acreage in Burkina Faso is 4.2 million hectare or about 75% of the total cultivated area. Maize is the third cereal after sorghum and millet. Maize cultivation is booming especially in the cotton zones where maize is integrated in the production system and can benefit from the inputs (fertilizer) used in cotton production. In 1985, only 9% of produced cereals were maize while in 2015 the share of maize in total cereal production was around 23%. The area under maize almost doubled between 2007 and 2015 when it reached more than 800,000 ha. (Table 1). Maize is of paramount importance during the lean season (period at the beginning of the rainy season when all crops are growing but where the previous year's cereal stocks are exhausted).[2] In Burkina Faso, maize is grown almost everywhere but mainly in AEZ4 which accounts for almost 59% of maize area and over 66% of total maize production in the country (Table 2 and Figure 1).

1 http://eatlas.resakss.org/Burkina-faso/en/

2 Période de soudure

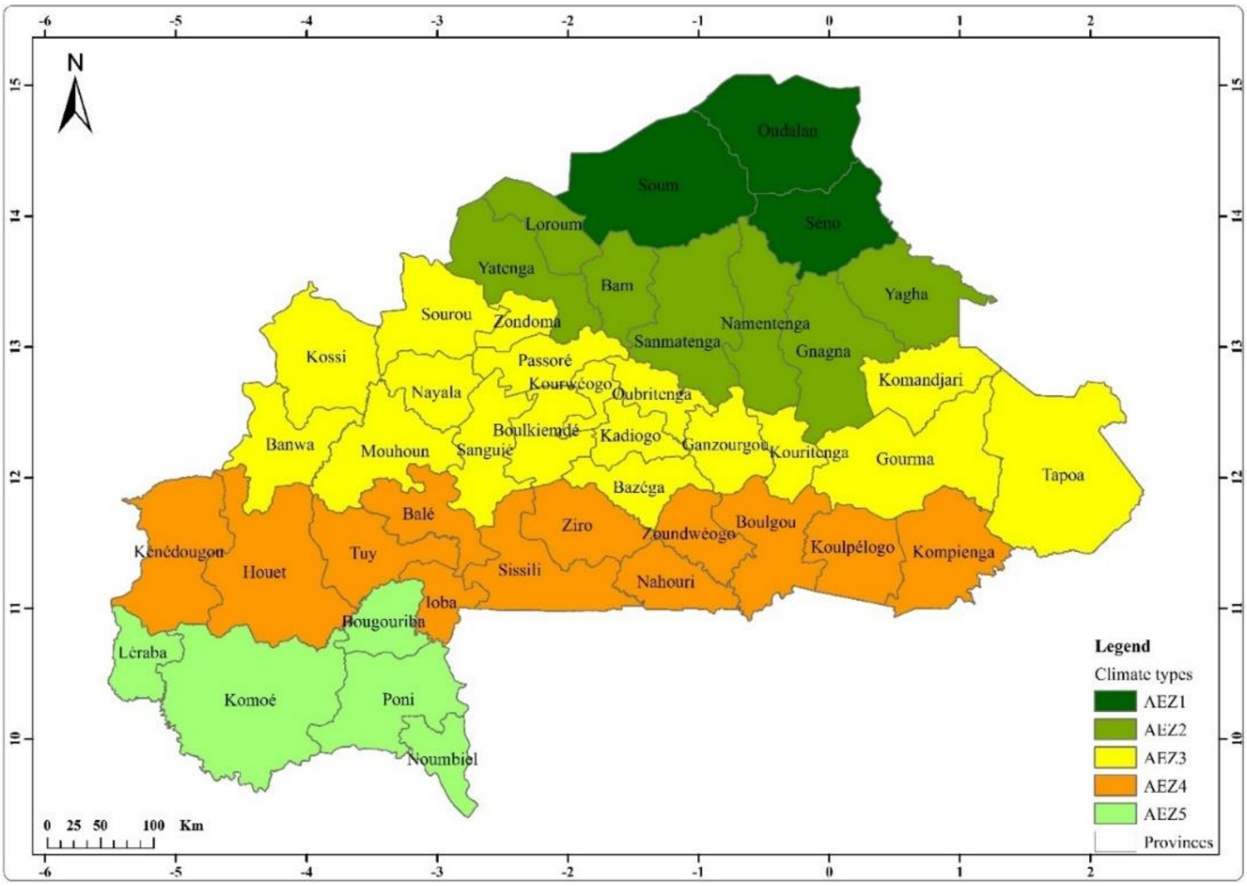

Figure 1: Spatial disaggregation of Burkina Faso into five AEZs

Source: Authors based on eAtlas. Note: Burkina is divided in five regions based on the length of growing period (LGP) but we only consider four regions as maize growing areas (LGP> 90 days). The spatial information of each region was provided as a shape file developed by Rezaei and Gaiser (2018). LGP for AEZ1 is 68-89 days; for AEZ2 90-119 days, AEZ 3 120-149, AEZ4 150-179 and AEZ5 180-209.

Table 1: Acreage for the main crops in Burkina Faso (2015)

Crops	Acreage (ha)	Shares
Cotton	**657,840**	**12.4%**
Cowpea	165,647	3.1%
Fonio	15,743	0.3%
Groundnut	432,665	8.1%
Maize	**820,117**	**15.4%**
Millet	**1,160,718**	**21.8%**
Potato	6,274	0.1%
Rice	**142,716**	**2.7%**
Sesame	400,255	7.5%
Sorghum	**1,444,937**	**27.2%**
Soybean	18,046	0.3%
Voandzou	45,348	0.9%
Yam	7,809	0.1%
Total	5,318,115	100%

Source: Authors based on eAtlas

Table 2: Burkina Faso maize agricultural statistics by AEZ

	AEZ1 provinces	AEZ2 provinces	AEZ3 provinces	AEZ4 provinces	AEZ5 provinces
	Oudalan, Seno, Soum	Bam, Namentenga, Sanmatenga, Gnagna, Loroum, Yatenga, Yagha	Banwa, Kossi, Mouhoun, Nayala, Sourou, Kouritenga, Boulkiemdé, Sanguié, Bazéga, Kadiogo, Gourma, Komandjari, Tapoa, Passoré, Zondoma, Ganzourgou, Kourwéogo, Oubritenga	Balé,Boulgou, Koulpélogo, Sissili, Ziro, Nahouri, Zoundwéogo, Kompienga, Houet, Kénédougou, Tuy, Ioba	Komoé, Léraba, Bougouriba, Noumbiel, Poni
Production	0.16%	1.69%	18.89%	66.28%	12.98%
Avg Yield (Kg/ha)	481	900	1230	1836	1437
Cultivated area	0.46%	3.25%	23.42%	58.53%	14.34%

Source: Authors' computations based on eAtlas

3. Methodology

3.1 Model Description

The CGE model customized to Burkina Faso's economy follows the standard model as provided by IFPRI (Lofgren et al., 2002) and the Partnership for Economic Policy (Decaluwé et al., 2012). The model is grounded in the neoclassical general equilibrium theory, i.e. producers and consumers respond to relative prices resulting from profit and utility maximizing behavior. Perfect competition prevails in the sense that producers and consumers take as given the relative prices that simultaneously equate the quantity produced to the quantity demanded. While all commodity markets follow the neoclassical market-clearing price mechanism, producer and consumer prices vary by exogenously given taxes and subsidy rates as well as margins rates.

This standard CGE framework is used to build up an agriculture-focused CGE (Ag-CGE) model for Burkina Faso. The model has been made agriculture-focused through the following features: separate agriculture and non-agriculture labor markets, separate urban and rural representative household groups, including welfare analysis and the imperfect integration of land markets, i.e. the land market is split into agroecological zones (AEZs). The CGE model includes various AEZs defined at subnational level with the objective of creating a consistency with the other components of the program. The CGE model is a single-country, multi-sector, multi-market model and solved for multiple periods in a recursive manner, ten years in the case of Burkina Faso.

The key feature of the model is on the supply side (Figure 2). The model features a nested production function, which integrates the disaggregation of agricultural production across the AEZs. Thus, a cost minimizing producer follows a four-level nested production function that reflects the imperfect combination of scarce resources, i.e. factors and inputs, through a Constant Elasticity of Substitution (CES) relationship. At level one, various categories of labor *l* are imperfectly combined into a labor composite, on the one hand, and region-specific land and fertilizer use, into a land-fertilizer composite, on the other. At this level, a quasi-fixed relationship is assumed, i.e. the elasticity of substitution is close to zero. At level two, composite labor and composite capital are mixed into a capital-labor composite and land-fertilizer bundles across regions are aggregated into one composite factor.[3] Flexibility in substituting the different components is assumed at this level, i.e. the elasticity of substitution is greater than one. At level three, the capital-labor composite and aggregate land-fertilizer bundle are combined into an extended value added; various inputs are also mixed into a composite bundle of intermediate consumption; a quasi-fixed relationship is also assumed at this level. At level four, the extended value added, and other inputs bundle are combined in a

3 This specification is under mild assumptions, a good approximation of regional production trees in the model (Hertel et al, 2008).

production function with a limited substitution possibility, i.e. the elasticity of substitution is less than one.

The derived demands for factors and inputs - labor by type, land by region, and use of fertilizer and other inputs - are specified. Within each region, an exogenous supply of land is assumed to be perfectly allocated across agricultural activities. Thus, a uniform return to land is observed across activities within each region. However, land supply is updated between periods to reflect natural extension. Also, the exogenous supply of labor meets the endogenous demand with a perfect competition market clearance assumption in rural areas, and imperfect competition in urban areas with an excess supply of labor. Fertilizer demand and supply follow the competitive market clearance setting. The volume of exogenous capital is sector specific within a given period but updated between periods according to the neoclassical rule of investment allocation across industries (Junk and Thorbecke, 2003).

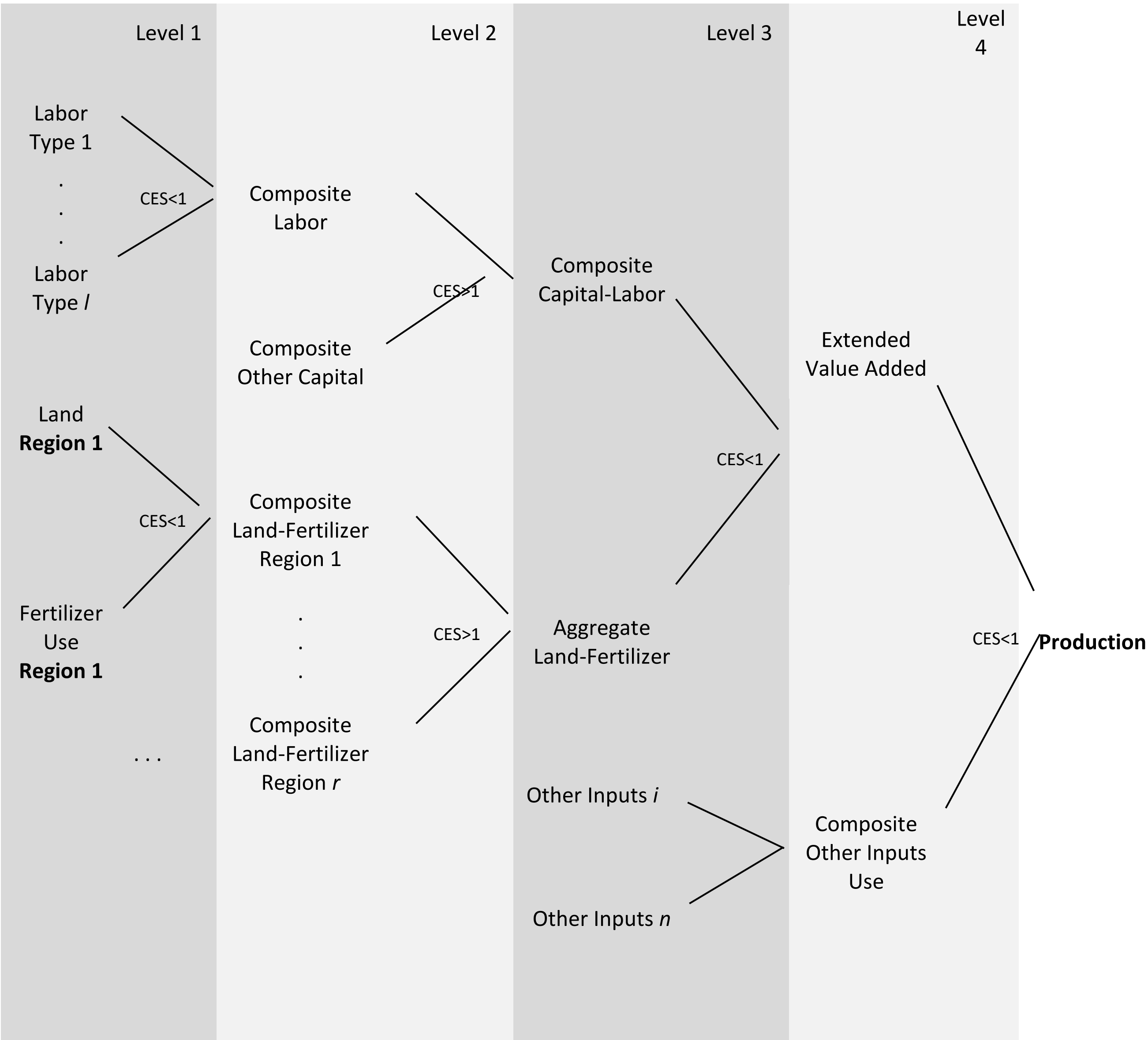

Figure 2: A Four-Level Nested Production Function

3.2 Data sources

The CGE model is calibrated using a Social Accounting Matrix (SAM). The economic model primarily uses the 2013 SAM built by Ouattara (2017). The SAM has several interesting features with regards to agricultural modelling. There are forty-six activities, including twelve agricultural activities, and forty-six commodities including twelve agricultural products. The SAM highlights the focus crops for Burkina Faso and particularly maize, which is the focus crop of this study. It accounts for two labor categories - agricultural and non-agricultural. Two categories of “capital” are highlighted: agricultural land and other capital.

The SAM includes 10 institutional accounts and four household categories (Tables 3 & 4). There are also four tax accounts linked to one government account, one corporation account, and one external account, i.e. the rest of the world. Finally, the SAM features a trade account for products that enter the market sphere and two capital accounts: gross fixed capital formation and changes in inventories.

Table 4: SAM household categories income repartition (in Millions of FCFA)

Household types	Label	Incomes
U1	Poor rural households	746,086
U2	Poor urban households	76,343
U3	Non-Poor rural households	2,479,793
U4	Non-Poor urban households	1,493,073

Source: Authors based on Ouattara (2017)

To customize the SAM to the scenarios to be simulated, regional disaggregated data at the AEZ level is required. Land income from the SAM is disaggregated by AEZ using production value and production area information at the province level. The information is provided at province level by Burkina Faso’s eAtlas.[4] Land income from the SAM is distributed across the AEZs using the most recent available data, which are from 2015. In every AEZ, the return to land is proxied by the production value per unit of harvested surface. The latter information and the harvested areas are subsequently used to split land across the AEZs for major crops highlighted in the SAM.

4 http://eatlas.resakss.org/Burkina-faso/

Table 3: SAM Labor and Capital Factors for agricultural commodities (in millions FCFA)

		Agr commodities												
		Maize (J1)	Rice (J2)	Other cereals (J3)	Roots & Tuber (J4)	Legumes (J5)	Cotton (J6)	Other oil seeds including Shea nuts (J7)	Other crops (J8)	Cattle livestock (J9)	Poultry breeding (J10)	Other animals breeding (J11)	Forests, Fishing, Hunting and activities related to forestry (J12)	**Total**
Production Factors	AGR Labor (F1)	106813	61023	223806	157163	67025	147499	168651	50882	488	91	665	6013	**990,118**
	Non AGR Labor (F2)	0	0	0	0	0	0	0	0	0	0	0	0	**-**
	Land AEZ1 (F3)	2	2	272	0	1	0	29	0	0	0	0	0	**306**
	Land AEZ2 (F4)	16	20	375	9	5	0	252	45	0	0	0	0	**722**
	Land AEZ3 (F5)	119	107	765	3	13	304	613	3645	0	0	0	0	**5,569**
	Land AEZ4 (F6)	297	179	300	121	9	719	556	13447	0	0	0	0	**15,628**
	Land AEZ5 (F7)	73	39	53	148	3	75	122	413	0	0	0	0	**925**
	Other capital (F8)	761	520	2647	421	46	1648	2358	26326	216808	98258	330466	204109	**884,367**
	Fertilizer AEZ1 (F9)	20	5	2014	0	8	0	1	0	0	0	0	0	**2,049**
	Fertilizer AEZ2 (F10)	145	48	2784	1	32	0	11	1	0	0	0	0	**3,022**

Fertilizer AEZ3 (F11)	1046	256	5675	0	91	1028	26	86	0	0	0	0	**8,209**
Fertilizer AEZ4 (F12)	2614	427	2223	15	62	2429	24	319	0	0	0	0	**8,113**
Fertilizer AEZ5 (F13))	640	92	394	18	22	253	5	10	0	0	0	0	**1,435**
Tot Agr Value Added	**112,548**	**62,718**	**241,307**	**157,898**	**67,316**	**153,956**	**172,649**	**95,173**	**217,296**	**98,349**	**331,131**	**210,122**	**1,920,463**
Tot Labor	**106,813**	**61,023**	**223,806**	**157,163**	**67,025**	**147,499**	**168,651**	**50,882**	**488**	**91**	**665**	**6,013**	**990,118**
Tot Land	**507**	**346**	**1,764**	**280**	**31**	**1,099**	**1,572**	**17,549**	**-**	**-**	**-**	**-**	**23,149**
Tot other capital	**761**	**520**	**2,647**	**421**	**46**	**1,648**	**2,358**	**26,326**	**216,808**	**98,258**	**330,466**	**204,109**	**884,367**
Tot Fertilizer	**4,466**	**829**	**13,090**	**34**	**214**	**3,711**	**68**	**416**	**-**	**-**	**-**	**-**	**22,828**
Tot capital	**5,227**	**1,349**	**15,737**	**455**	**261**	**5,359**	**2,426**	**26,742**	**216,808**	**98,258**	**330,466**	**204,109**	**907,196**

Source: Authors' computations based on the SAM (Ouattara 2017)

3.3 Improvement of agricultural production efficiency

This scenario is informed by the results from the agricultural typology analysis (Maruyama et al. 2018). Maruyama et al (2018) constructed agricultural typologies of microregions in Burkina Faso to identify micro-regional level opportunities, bottlenecks and investment gaps based on the concept of the production possibilities frontier applied to farm activities, drawing on highly detailed household-level survey and geospatial data on agroecological conditions, accessibility and poverty. This typology scenario considers that all farmers move from their current level of efficiency and the annual productivity growth rate by AEZ required to catch up with the frontier is calculated. The CGE implementation consists of increasing the baseline composite land-fertilizer scale parameter by AEZ and agricultural activity. In the analysis, we consider a 10-year timeframe to catch up with the frontier.

Table 5: Maize annual productivity growth required by AEZ (Typology scenario)

Scenario	**AEZ1**	**AEZ2**	**AEZ3**	**AEZ4**	**AEZ5**
Typology	7.72%	7.16%	4.93%	4.12%	7.55%

Source: Maruyama et al. (2018)

Table 5 shows that the required growth rates in maize productivity ranges from 4 to almost 8 percent depending on the AEZ. Producers in the center of the country are more efficient and require lower productivity growth rates to catch up with the frontier. Though current growth rates at the AEZ level are not available, maize production has witnessed strong growth with annual production tripling from 0.5 to 1.5 metric tons between 2002 and 2012 (FAO 2019) suggesting that the required growth rates are attainable.

3.4 Innovations in agricultural technology

Here we focus on what can be considered as expanding the frontier. Agricultural innovations are introduced at the AEZ and agricultural activity levels. Rezaei and Gaiser (2018) proposed several innovations in maize production and one scenario will be modeled here is a combination of the nitrogen application rate, new cultivars and the sowing date (Table 6). To model these technologies, 30 years (1980-2010) of climate data were used as well as soil and management information obtained from global datasets at 0.5° x 0.5° spatial resolution. The crop modelling framework SIMPLACE was used to test the effects of innovation packages at the country level.

Table 6: Crop scenario description

Scenario	Description
Baseline	conventional cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system
Crop	New cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system

Source: Rezaei and Gaiser (2018)
Note: The same crop scenario is used in all AEZs

The economic modeling primarily uses information on the changes in nitrogen applications and yields. The composite land-fertilizer scale parameter by AEZ and agricultural activity is then changed to reflect the improvement in the productivity level triggered by the technological innovations.

4. Results

As described above the innovations simulated in the model consist of an improvement in agricultural production efficiency (typology scenario) and an innovation in agricultural technology (crop scenario). Below we will show and describe simulation outcomes.

4.1 Changes in production

Figure 3 shows the changes in maize production under the two scenarios. As expected, there is an increase in maize production in both scenarios. However, the increase is more pronounced in the typology scenario (+35%) compared with a 5% increase in the case of the crop scenario after 10 years. This moderate increase for the crop scenario could be explained on the one hand by the fact that Burkinabe maize producers already use improved, synthetic, composite and hybrid varieties with high productivity. On the other hand, the maize sector already benefits from the relatively good organization of the cotton sector and its use of fertilizer.

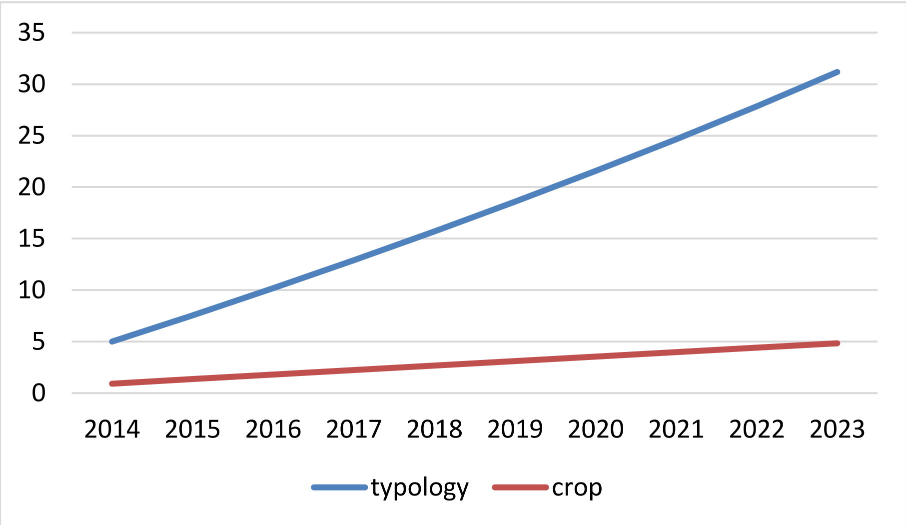

Figure 3: Changes in maize production with respect to the baseline (%)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

Results of the simulations are also computed for other sectors that are directly or indirectly relate to the maize sector. The SAM analysis reveals that the grain processing and beverage sectors (Figures 4 and 5) also consume maize. Figure 4 shows that the increase in maize production does not substantially affect the grain processing sector. There is certainly an increase in this sector in the two simulated scenarios. However, this increase remains very low and does not exceed 0.30% after ten years. The increase in maize production does not seem to boost the processing sector, which is one of the weak links in this maize value chain in Burkina Faso.

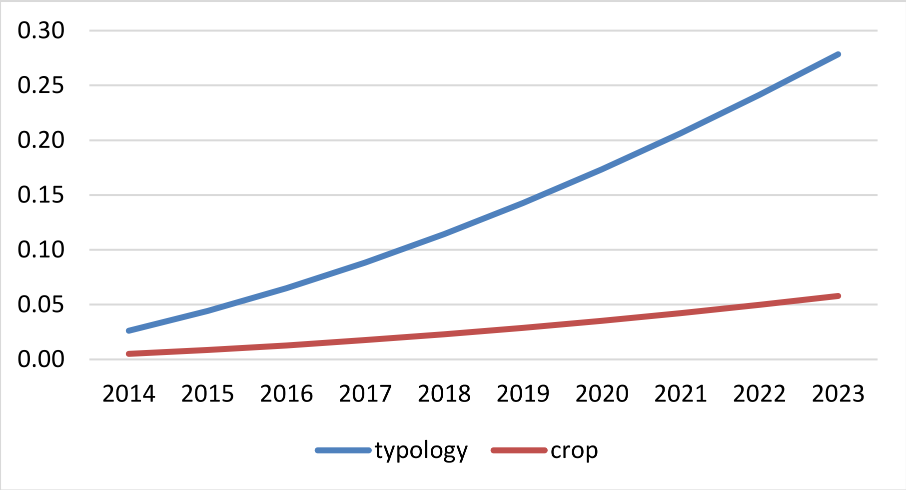

Figure 4: Grain processing (changes %)

Source: Authors' computations
Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

Figure 5 shows that the technological innovations in the maize sector do not positively affect the production of beverages. In fact, slight declines are observed for both scenarios. This could be explained by the fact that the main raw material for making traditional beer in Burkina remains sorghum. [5]

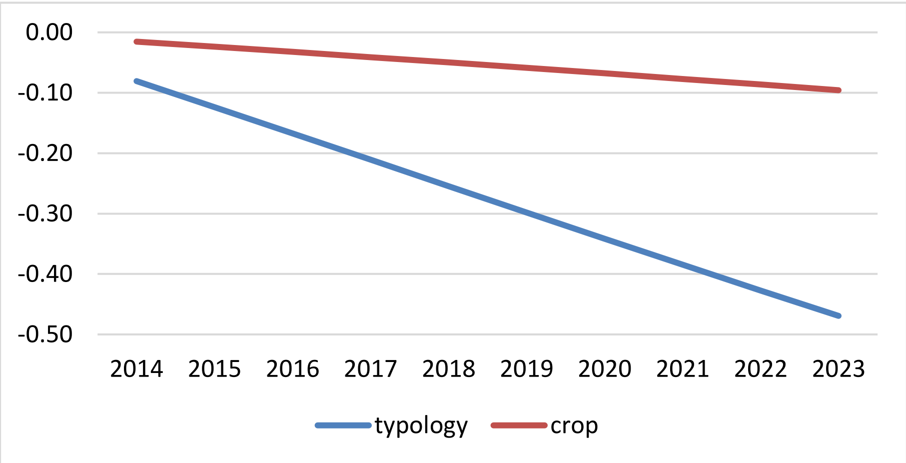

Figure 5: Beverage production (changes %)

Source: Authors' computations
Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

5 The Dolo sorghum beer brewed in the famous artisanal doloteries that dot urban neighborhoods and villages. The sorghum and millet cake, waste of the doloteries, constitutes the base of the food of the domestic pig farms. However, a small portion of maize is also used for Dolo but due to the bitterness of the alcohol produced, it is usually mixed with grains of sorghum and millet.

We also added the poultry sector (Figure 6) to see if the introduction of innovation in the maize sector could affect this sector.

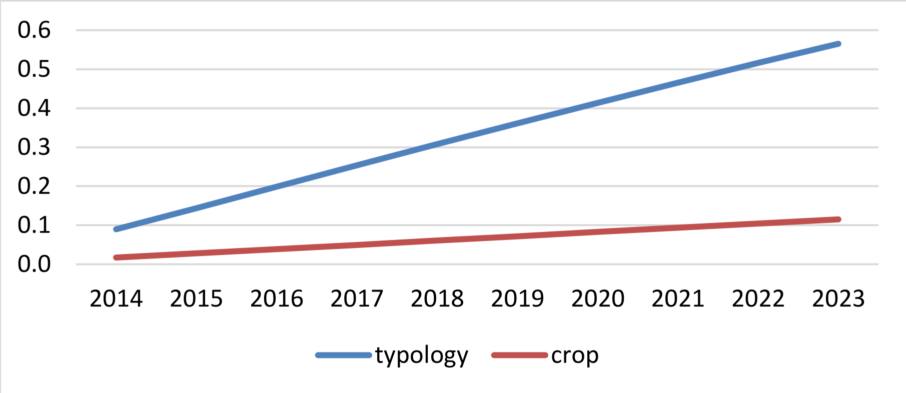

Figure 6: Poultry production (changes %)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

Like the grain processing sector, the increase in the maize sector does not have a significant impact on poultry production in Burkina Faso. Indeed, there is an increase of less than 1% after 10 years. This could also be explained by the fact that poultry production in Burkina Faso is not industrialized and does not produce broilers. In addition, this sector tends to use residues of sorghum and millet rather than maize as poultry feed.

Finally, effects of technological innovations in the maize sector on cotton production were considered because maize in Burkina Faso is mainly produced in the cotton zones. Figure 7 shows that the introduction of technological innovations in the maize sector does not affect cotton production.

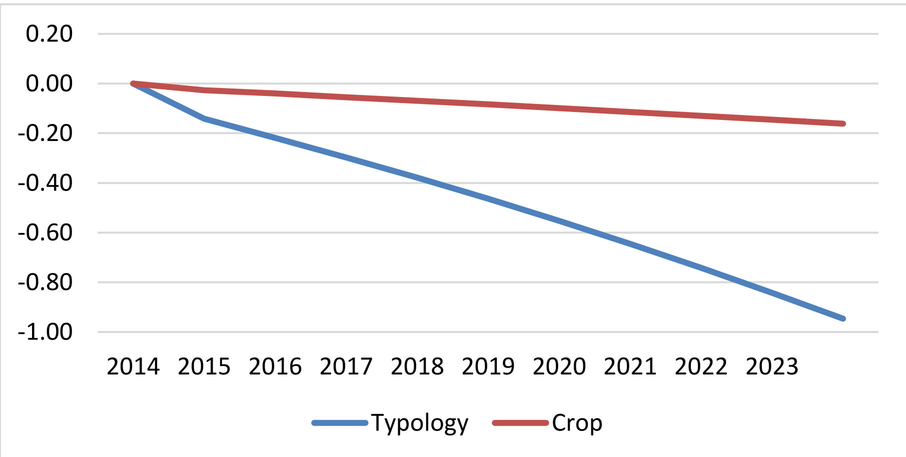

Figure 7: Cotton production (changes %)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

4.2 Impacts on growth

Figures 8 and 9 show the impact of crop and typology scenarios on overall gross domestic product (GDP) and agricultural GDP growth.

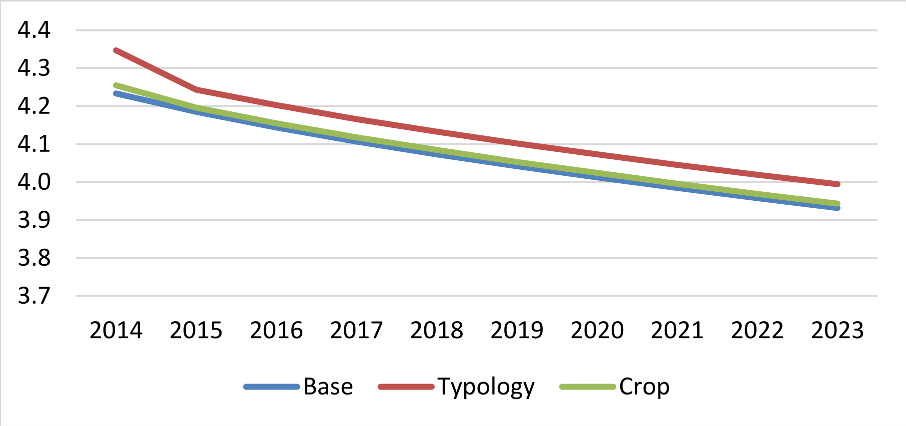

Figure 8: GDP (% change)

Source: Authors' computations

Note: Base= Baseline scenario; Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

At the macro level, the typology scenario seems to be more beneficial for the Burkina Faso economy than the crop scenario and the baseline scenario (Figures 8 and 9). Indeed, the average growth rate for the typology scenario is greater than those for crop and baseline scenarios. It is above 4.1% for the considered periods (Figure 8). Regarding the agricultural growth rate, it is also above 3% for typology scenario for the simulated periods and greater than the agricultural growth rates observed for other scenarios (Figure 9).

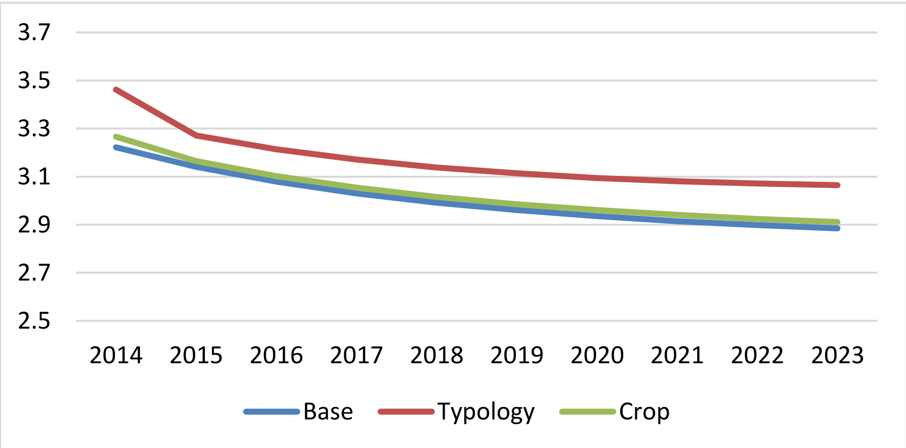

Figure 9: Agricultural growth rate (% change)

Source: Authors' computations

Note: Base= Baseline scenario; Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

4.3 Agricultural trade balance variation

The typology scenario seems to improve the agricultural trade balance of Burkina Faso. In fact, Figure 10 shows that there is an 8% improvement compared to the baseline while it is almost stable in the crop scenario. This could be explained by the substantial increase in maize production induced by the typology scenario (+35%). This could increase maize exports, which are estimated at around 5% in the SAM used in this study as maize consuming sectors (processing and beverage sectors) do not increase their demand for maize. At the same time, the simulation results revealed a 70% decrease in maize imports in the case of the typology scenario in comparison to the baseline scenario and a 20% decrease for the crop scenario.

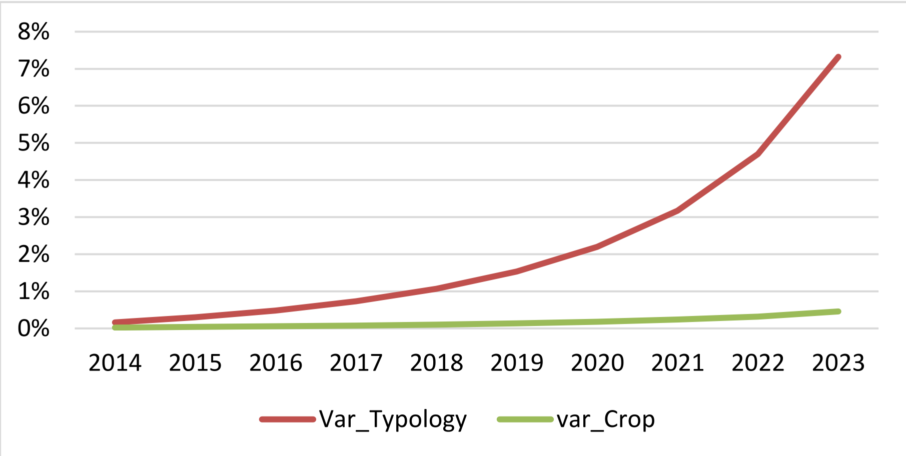

Figure 10: Agricultural trade balance variation with respect to the baseline

Source: Authors' computations

Note: Var_Typology = Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); Var_crop = crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

4.4 Returns to factors

The introduction of technological innovations in the maize sector has led to the decline in the return of the land in the main production area AEZ4. This decrease is quite significant (around 15%) in the typology scenario (Figure 11).

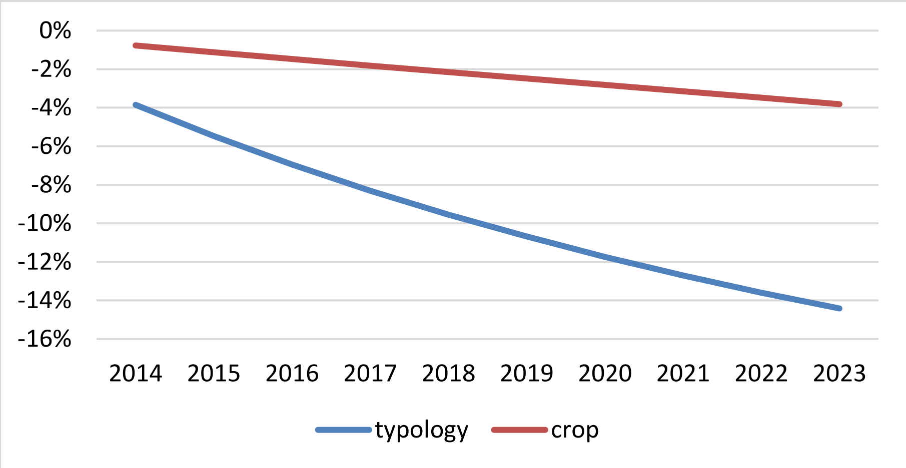

Figure 11: Changes in Return to land in AEZ 4 with respect to the baseline (Maize sector)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

This could be explained by the intensification induced by this scenario that would require less land use. On the other hand, there is an increase in wages for maize producers. However, this increase is more pronounced in the typology scenario, which is based on an improvement in the technical efficiency of the producers. However, this increase remains low in absolute and is less than 1% (Figure 12).

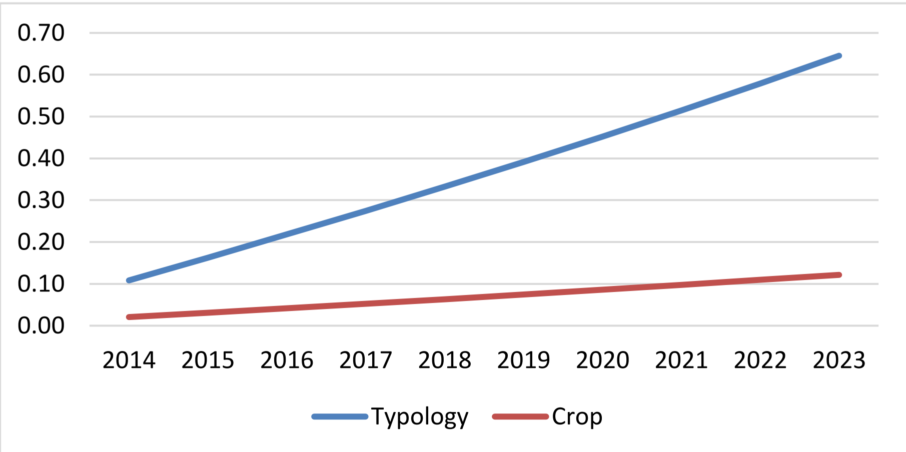

Figure 12: Maize sector wage variation (%)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

4.5 Welfare variation

4.5.1 Total welfare variation (EV in % of disposable income)

The innovations introduced in the maize sector seems to be beneficial to consumers in an aggregated way. In fact, the Equivalent Variation (EV) expressed as a percentage of disposable income shows an increase of 8% and about 2% respectively for the typology scenario and the crop scenario (Figure 13). The equivalent variation is the change in wealth, at current prices, that would have the same effect on consumer welfare as the change in prices with income unchanged. Given the importance of maize in Burkina Faso's diet, this result would make it possible to cope with food insecurity, particularly during the "periode de soudure" (period at the beginning of the rainy season when all the crops are growing but where the grain stocks of the previous year are exhausted). Cereal crops are of paramount importance in the diet: 90% of the calorific needs of the population derives from cereal intake with an average of 180kg consumed per person per year (141kg in urban areas, 186kg in rural areas). In the next subsection, we will describe the differential impacts of the technological innovations on the household types identified in Table 4.

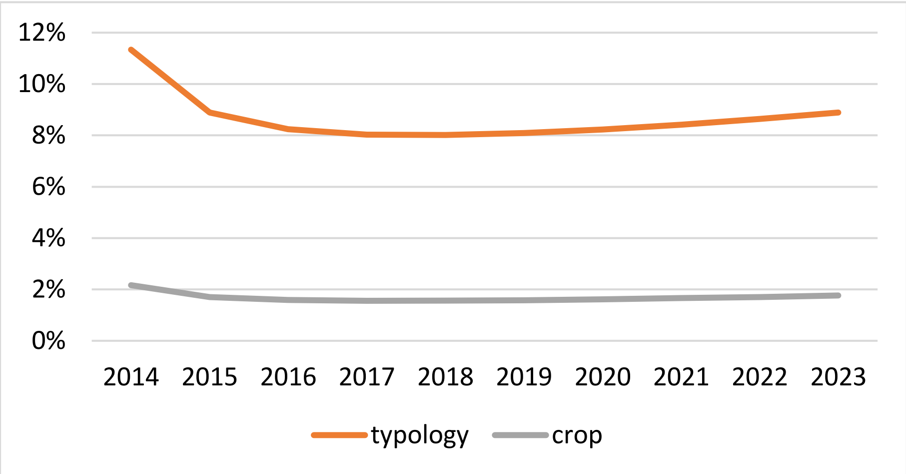

Figure 13: Total welfare variation (EV in % of disposable income)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

4.5.2 Household welfare

Four household profiles were identified as part of this work. Figures 14, 15, 16 and 17 show welfare gains in comparison with the baseline scenario. In general, the introduction of innovations in the maize sector seems to benefit to all the household types. Regardless the scenario and household profile considered, a welfare improvement is observed compared to the baseline scenario.

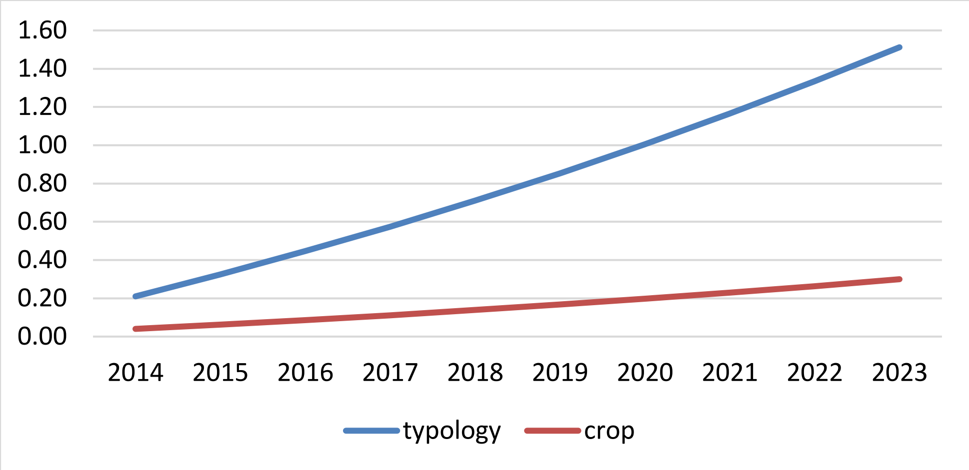

Figure 14: Changes (base vs scenarios) in EV for poor rural households (% share of initial income)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

In addition, the welfare gains are more pronounced in the typology scenario for all profiles. Urban poor households (Figure 15) appear to be the most positively affected regardless of the scenario. If we consider only the typology scenario, rural non-poor (Figure 16) and urban poor households benefit more from the introduction of innovations in the maize value chain.

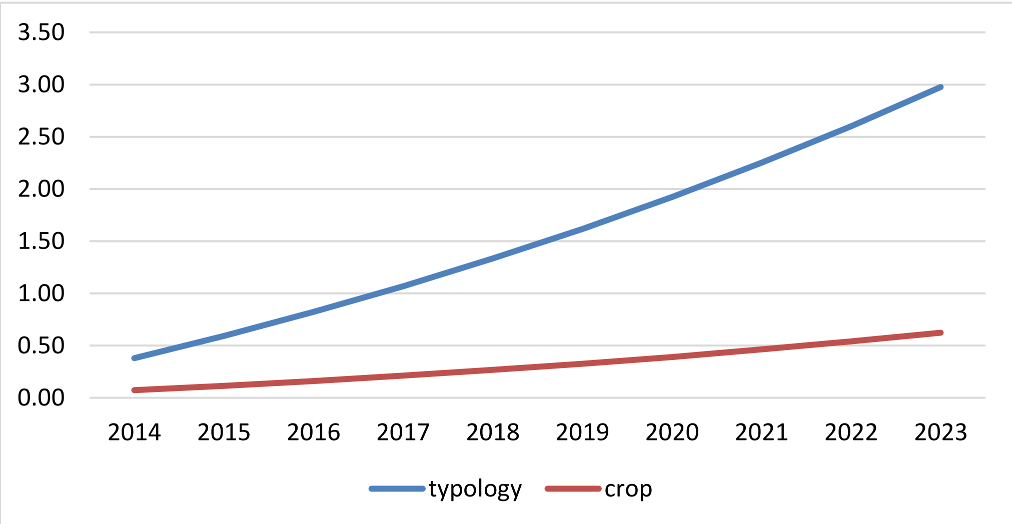

Figure 15: Changes (base vs scenarios) in EV for poor urban households (% share of initial income)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

This can be explained for rural household profiles by the rate of maize penetration in rural food habits. In fact, the consumption of rural households of all forms of maize accounts for about 47% of total consumption. Moreover, in rural areas, this cereal is of paramount importance during the "période de soudure". Regarding, the urban poor, these households are in general composed of people originating from the countryside with a strong maize habit consumption. Looking at the income side, we noticed that urban poor households are the poorest (Appendices 2 and 3) and maize consumption of these households increases with their income. In other words, the introduction of innovations in the maize value chain seems to be pro-poor.

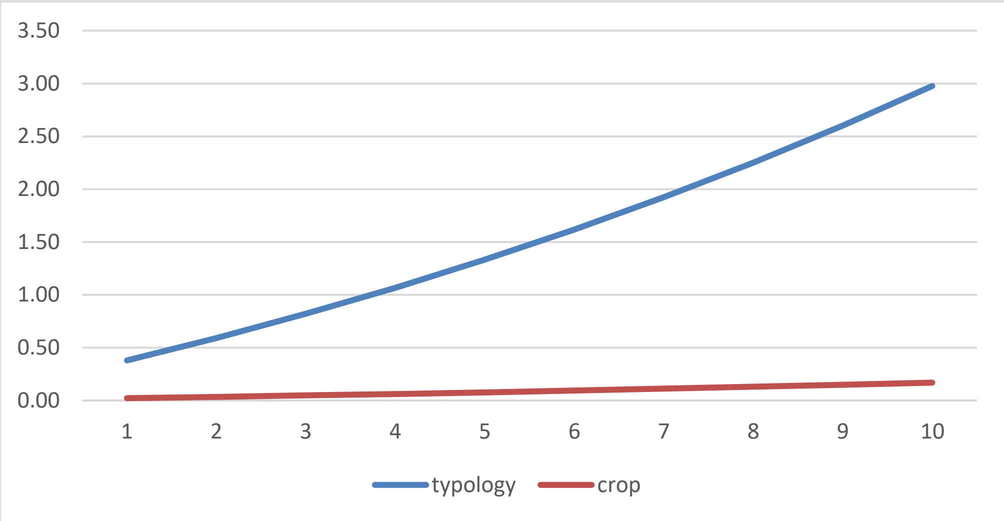

Figure 16: Changes (base vs scenarios) in EV for non-poor rural households (% share of initial income)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

On the other hand, non-poor urban households seem to be less dependent on maize for their food and often rely on rice, which seems to be gaining ground in urban areas. Indeed, rice is synonymous with improving the standard of living of some families.

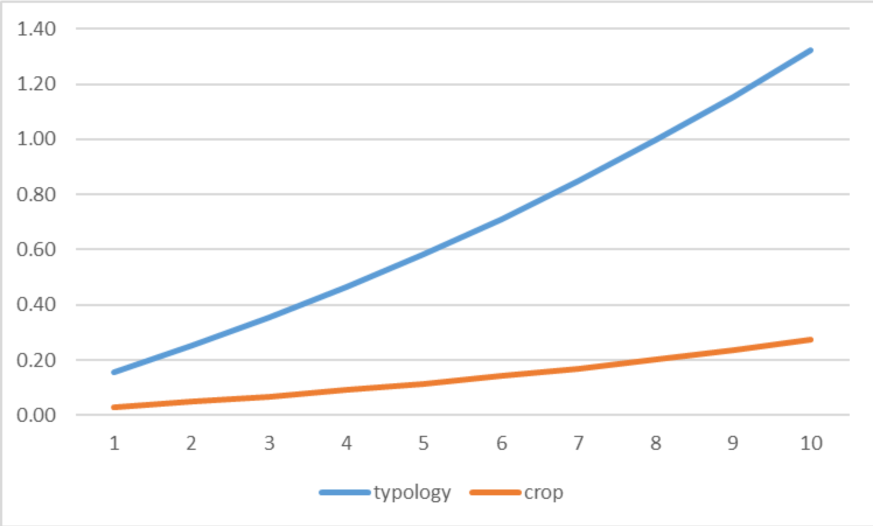

Figure 17: Changes (base vs scenarios) in EV of non-poor urban households (% share of initial income)

Source: Authors' computations

Note: Typology= Typology scenario, which is increase in maize productivity in different AEZs (7.72% in AEZ1, 7.16% in AEZ2, 4.93% in AEZ3, 4.12% in AEZ4, 7.55% in AEZ5); crop= crop scenario, which is a new cultivar, baseline nitrogen use (5kg/ha), typical sowing date, rainfed system.

5. Public spending increases

Table 7 presents an estimate of the cost required in terms of public expenditure to produce the crop and typology scenarios. The table shows that to achieve these two scenarios, it is necessary to increase, respectively, the value added of maize by 3% and 17% over the entire simulation period (10 years). Public expenditure needs to increase by 26% during the first five years of simulations to increase productivity and reach the target of 17% as required by the typology scenario. For the crop scenario, the target of 3% can be reached using the same procedure, increasing investment spending by around 10% for the first five years of simulation.

To replicate the changes, we implement an exogenous increase in public expenditure which will in turn trigger productivity growth until the targets in terms of total value-added changes are reached. Our starting value for the share of agriculture public expenditure in total government expenditure is 9% (ReSAKSS, 2017).[6] We also assume that the adjustment in terms of public spending takes place within nonagricultural sectors, the share of which will decrease to increase spending in agriculture.

Table 7: Required public expenditure shares

Scenarios	Value added variation	Actual public expenditures shares of the maize sector	Required public expenditures shares of the maize sector
Crop	3%	0.37%	0.61%
Typology	17%	0.37%	1.56%

Source: Authors' computations

The study revealed that public expenditure shares going to the maize sector must be raised to at least 0.61% to achieve the crop scenario and 1.56% to achieve the typology scenario over 10 years.

6 www.ReSAKSS.org

6. Conclusion

The agricultural sector is an essential component of Burkina Faso's economy. It contributes 35% to the Gross Domestic Product (GDP) of the country and employs 82% of the active population. The major challenge of the rural sector for the coming years is to ensure food and nutrition security for an increasingly growing population in the context of climate change.

In this study we have evaluated impacts of the introduction of technological innovations in the maize value chain in Burkina Faso. For the two scenarios – catching up with the production frontier and expanding the frontier – our results showed prospects of gains for the economy. Welfare analyses performed showed welfare gains for all household profiles studied. Finally, the study found that a total increase of about 2% of public expenditure in this sector over 10 years is required to achieve the simulated results.

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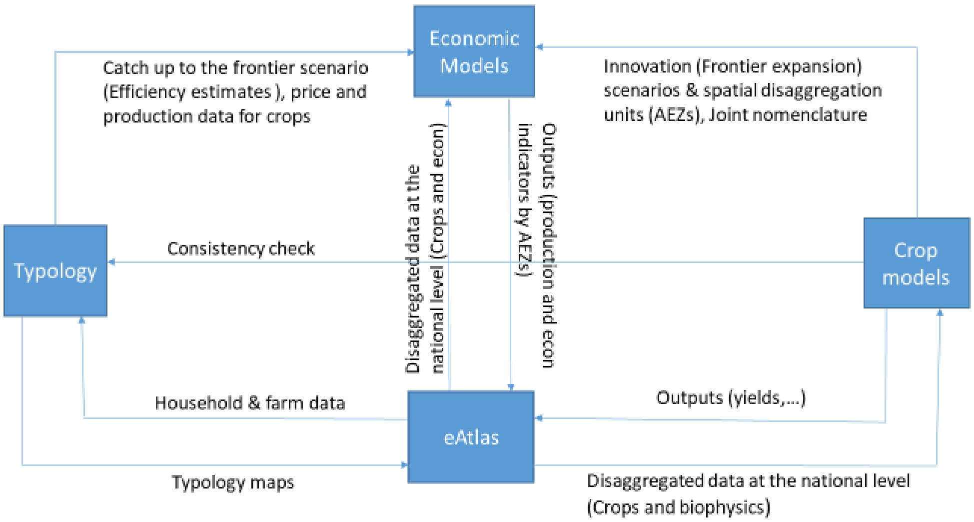
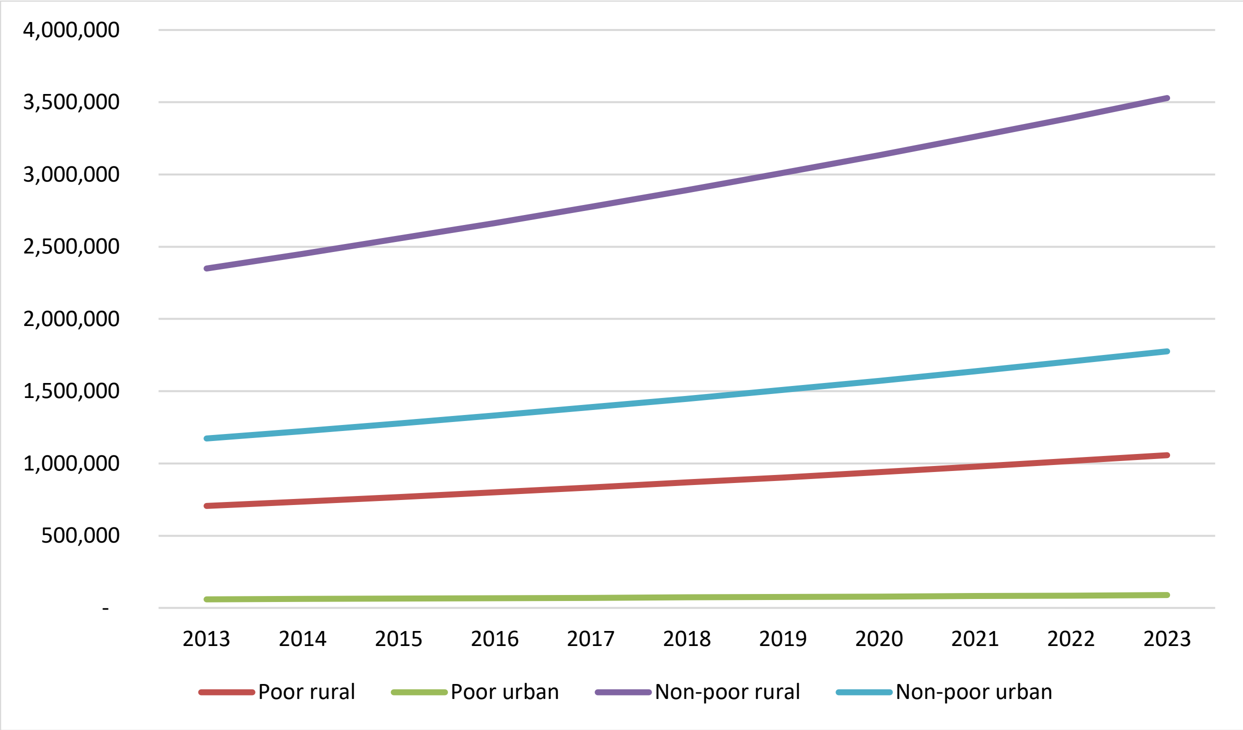
8. Appendices

Appendix 1: Link between components of PARI

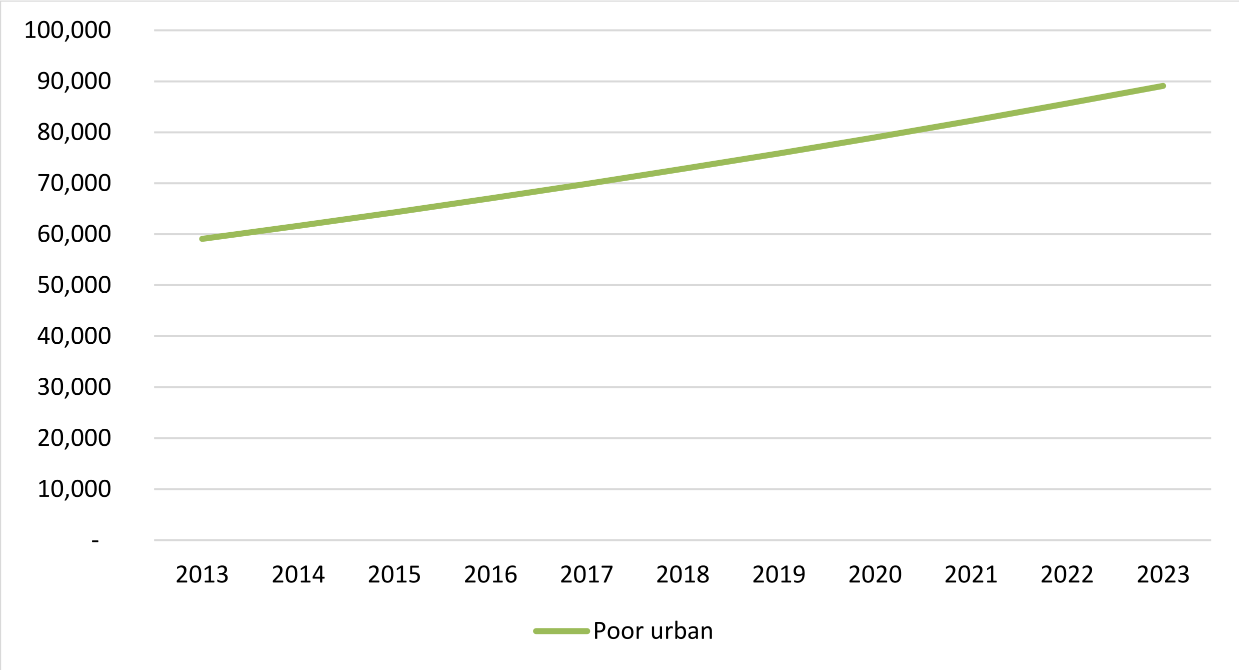


Appendix 2: Household disposable income in FCFA



Source: Authors

Appendix 3: Poor urban households' disposable income in FCFA



Source: Authors