Global impacts of targeted interventions in food security crops – the case of potatoes in developing countries

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Selected Poster prepared for presentation at the International Association of Agricultural Economists (IAAE) Triennial Conference, Foz do Iguaçu, Brazil, 18-24 August, 2012.

1 Introduction

After decades of declining trends, real global food prices have been rising since the early 2000s, culminating in the food price crisis of 2007/2008 (Headey and Fan, 2008; Masters and Shively, 2008). Not least due to these price rises, in the period 2000/02 to 2006/08 the absolute number of undernourished people in the world has increased to 850 million (FAO, 2011). While these figures still represent a reduction in the proportion of undernourished people in the population, the fact that the fight against hunger practically has come to a halt since the mid years of that decade has brought issues of food security back on the public and scientific agenda (FAO, 2008; G20 Agriculture Ministers, 2011; IAASTD, 2009; United Nations, 2010). A widely cited figure brought forward by the FAO states that global demand for food and feed would grow by 70% during the first half of the 21st century (FAO, 2009). Although the consequence often drawn from this figure that agricultural production would have to rise by this amount may be overstated (Grethe et al., 2011), a clear response to this challenge is indicated. In this context, the CGIAR calculates that it would be necessary to raise agricultural productivity by 0.5% over the baseline growth across all regions in the world to achieve a food secure world by 2025 (CGIAR, 2011; Nin Pratt and Fan, 2010).

A significant contribution to food security and the enhancement of the capacity of the global food system to cope with the challenges ahead can be made by roots and tubers. Roots and tubers have multiple and important roles in local food systems and for food security. They are well suited for cultivation in environmental conditions where other crops may fail, and their short and flexible vegetation cycle makes them well suited for intercropping with other crops (FAO, 2008). Thus, they help to increase the availability of food and raise the aggregate efficiency of food systems.

By providing income generation opportunities as cash crops and generating employment, roots and tubers contribute to alleviating poverty (Scott et al., 2000a). Further, they represent important sources of energy, with a high delivery of energy per ha and are rich in micronutrients (Alexandratos, 1997; Thiele et al., 2010). During the food price crisis in 2007/2008, prices of roots and tubers—largely nontraded crops—were significantly less affected by the price increases in international markets (FAO, 2008). This highlights the contribution these crops can make to a more stable world food system. The fact that roots and tubers are grown in regions with high incidences of poverty, malnutrition and food insecurity underlines their particular importance (Bruinsma, 2003).

In terms of quantities produced and consumed, potato (*Solanum tubero-*

sum L.) is the most important representative of roots and tubers (Horton, 1988), being the fourth most important food crop in the world (Thiele et al., 2008). In 2009, world production reached 330 million tons, of which 18 million tons were produced in Africa, 16 million tons in South & Central America, 59 million tons in South & West Asia and 89 million tons in East Asia & The Pacific (FAO, 2012).

Over the past five decades, potato yields have been rising constantly. The major part of production growth, however, came from an expansion in the area of production (FAO, 2012). This points to a high potential for yield improvements (Scott et al., 2000b) and highlights the role technological innovations aimed at increasing productivity can play. It is recognized that technological improvements in potatoes have so far been an underexploited resource (Alexandratos, 1997). In fact, past impact evaluation studies have shown the potentially high returns on investments in research on potato technologies and the high impacts these technologies can have on poverty and hunger (Fuglie and Thiele, 2009).

In spite of their high importance and significant potential, potatoes have received limited attention in global scale studies which analyze the role and contribution of the crop to the world food system. Horton (1988) compiles a comprehensive set of FAO statistics about global production, consumption, international trade and prices of different roots and tubers crops. Along with a short characterization of the respective production systems, the major trends for the period from 1961-85 are presented. A publication by FAO/CIP (1995) describes the global potato economy in the early 1990s, finding continued increases in global production, with rapid growth in developing countries and slow growth, stagnation and even reduction in developed countries. Thereby, the major contribution in production growth comes from Asia. Processing is identified as the fastest growing sector. The study also applies a simulation model to project supply and demand trends up to 2000, but provides no details on this model.

Walker et al. (1999) carry out an analysis of the global patterns and trends in potato demand and production. The authors present a conceptual framework of the development of supply and demand, which includes the diversification away from potato as a staple food with rising incomes as a major demand trend. On the production side, the model incorporates increasing specialization and commercialization of potato production with ongoing economic growth. Developing a global map of the distribution of potato area the authors point to an expansion of potato production and consumption in Asia, in particular in the Indo-Gangetic Plains and China.

Scott (2002) undertakes a critical review of the Walker et al. study and confirms its findings of production increases in many developing countries,

and the stagnation or contraction of production in many developed countries. The author points out that potatoes are often a high priced vegetable in developing countries and a cheap staple food in many developed countries and emphasizes diverse patterns and trends for developing and developed regions, hence questioning the applicability of a single, stylized model. The author also highlights the importance of potato as a contributor to alleviation of food shortages, for the improvement of rural incomes and poverty reduction.

Recognizing the relative scarceness of publications with projections on roots and tubers, Scott et al. (2000a,b) provide a first study which applies a rigorous quantitative simulation modeling framework and deals explicitly with potatoes. The authors employ the International Model for Policy Analysis of Agricultural Commodities and Trade (IMPACT) of the International Food Policy Research Institute to project global production, utilization and trade of root and tuber crops from 1993 to 2020. On the basis of two simulated scenarios, the authors confirm the findings of previous studies. Potato demand will increase globally, in particular in developing countries and especially Asia and Sub-Saharan Africa (SSA). On the production side, about 80% of the projected absolute increase in potato production will take place in developing countries and there will be significant area and yield growth in SSA. The authors call for continuous development and diffusion of improved technologies in order to maintain a sustained development of the roots and tubers sectors in developing countries

The present study takes into account the role of potatoes in the global food system and seeks to contribute to the current discussion on agricultural research for food security. To this end, an updated and rebuilt version of the IMPACT-WATER model (Rosegrant et al., 2008) is applied to assess the global impacts of targeted interventions in potato productivity. The calculations of the CGIAR (2011) are taken as a benchmark and a productivity shock of annual potato yield growth which is by 0.5% higher than the baseline growth rates is applied to 30 developing countries, which, based on combined indicators of potato production and livelihoods, have been identified by the International Potato Center (CIP) as priority regions for potato research (Thiele et al., 2010).

This exercise not only provides quantitative evidence on the likely impact of the interventions on the target countries themselves. It also aims at shedding light on the likely effects on non-target regions and on the world as a whole. Will the intervention be strong enough to generate significant impacts in the target countries? Will there be perceivable effects on a global scale? What kinds and magnitudes of spillover effects to other countries and markets can be expected?

2 Methodology, Scenario and Simulations

For the present study, we use an updated and rebuilt version of the IMPACT-WATER model (Rosegrant et al., 2008).[1] IMPACT-WATER is an integrated modeling framework which combines an economic global agricultural sector model with a water simulation model. Figure 1 represents the basic setup of this model. A food module projects agricultural production, demand, trade flows and prices on a regional scale and provides estimates of global food security. The food model is connected to a water simulation model, which simulates water availability for agriculture and other uses. The model works as a multi-period model. The current projection horizon implemented in IMPACT is from 2000 to 2050, but for the present purpose only the period to 2025 is considered.

The food module of the model is a partial equilibrium representation of the global agricultural sector. It comprises 40 agricultural commodities and distinguishes 155 regions and 126 water basins, which combine to 281 food production units (FPUs), thus offering a disaggregation at the sub-national level. Crop production takes place at the level of the FPUs and is distinguished by rainfed and irrigated production. For each period t, FPU n and commodity i, agricultural production is depicted by isoelastic functions for area AC and yield YC:

$$AC_{tni} = \alpha_{tni} \times (PS_{tni})^{\varepsilon_{iin}} \times \prod_{j \neq i} (PS_{tnj})^{\varepsilon_{ijn}} \times (1 + gA_{tni}) - \Delta AC_{tni}(WAT_{tni}) \quad (1)$$

$$YC_{tni} = \beta_{tni} \times (PS_{tni})^{\gamma_{iin}} \times \prod_{k} (PF_{tnk})^{\gamma_{ikn}} \times (1 + gCY_{tni}) - \Delta YC_{tni}(WAT_{tni}) \quad (2)$$

The supply QS of each commodity for each region is:

$$QS_{tni} = AC_{tni} \times YC_{tni} \quad (3)$$

Thus, agricultural production is assumed to be a function of input prices PS, output prices PF, a water variable WAT and specific shifters gA and gCY, which incorporate intrinsic changes in area and yields. The production of livestock is represented by a similar set of functions for the number of animals and yields per head.

[1] This section mainly draws on Rosegrant et al. (2008). For a more detailed documentation of IMPACT, the interested reader may refer to that document.

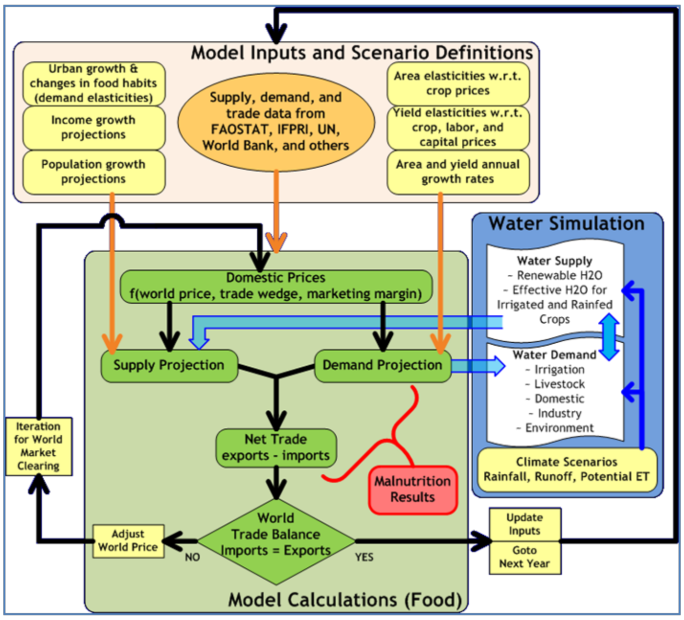

Figure 1: Schematic representation of IMPACT-WATER. Source: Rosegrant et al. (2008).

On the demand side, a set of separate functions is used to represent different demand components, namely food, feed, biofuels and other uses, which add up to total demand. In this system, food demand, again represented by an isoelastic function, is a function of own- and cross prices, income and population size. Feed demand is a fixed share of total supply, adjusted for price effects and technological progress in feed efficiency. Demand for biofuels is a function of government blending mandates, energy prices and policy support provided to producers.

The individual regions are connected to each other via trade. Net trade adds to domestic supply and stocks to equilibrate supply and demand. Global demand for each commodity is brought into equilibrium by an endogenous world market price, which clears the world market, determining domestic producer and consumer prices for all commodities.

A malnutrition module calculates the percentage of malnourished children based on the per capita availability of food calories obtained from the simulations, representing a basic indicator for food security.

The water simulation model predicts the availability of water for agricultural production in each FPU. The model equilibrates the supply of water within each river basin with the demand from different sources.

The points of entry to simulate the impacts of production side interventions to raise yield levels are the yield growth rates gCY in Equation (2).

In its standard version, the IMPACT-WATER model includes intrinsic yield growth rates, which reflect the baseline development of agricultural production in what can be called a "'business-as-usual"' scenario without any particular additional intervention. Any factor added to these baseline growth rates represents accelerated growth in yields.

The productivity shock applied for this paper is based on the figure of 0.5% cited by CGIAR (2011) as the additional growth in agricultural productivity necessary to achieve a food secure world by 2025. As this figure refers to a global scale and to all major crops, its achievement clearly would represent an undertaking of considerable scale and scope. In fact, the estimate is that roughly a triplication of the current investments into agricultural research for development to US$ 16.4 bn by 2025 will be required (Nin Pratt and Fan, 2010).

For the present study, a more limited effort is assumed. First, we restrict the assumed productivity increase to the potato crop only. Second, we limit the geographical scope to a set of 30 countries which have been identified by the International Potato Center (CIP) as those regions in which increasing potato productivity is most likely to enhance the livelihoods of most disadvantaged parts of the population (Theisen and Thiele, 2008; Thiele et al., 2010). The authors characterize each country of the world by the overlay of a composite livelihood score and the importance of potatoes. The livelihood score takes into account aspects of poverty, malnutrition, child mortality and maternal mortality and assumes values between 0 and 5, with higher values representing poorer conditions in terms of livelihoods. The importance of potatoes is expressed in terms of production per capita in each region and subdivided into six groups according to production levels). The higher the livelihood score and per capita production the higher is the priority for agricultural research for development oriented towards the potato crop (see Figure 2).

For the current study, all countries which have at least one region in the three higher levels of the livelihood score (i.e. livelihood scores of 3 or higher) and potato production of more than 30 kg per capita are identified as target areas. Following this approach, a number of 30 developing countries and transition economies are selected for the intervention. Table 1 lists the countries to which the productivity shock is applied.[2] Columns 2 and 3 of the table present statistics on production and food consumption of potatoes

[2]The number of 30 regions refers to the regions used in IMPACT, which uses some aggregates consisting of several countries, such as Central South America (Bolivia and Paraguay) or Northern South America (Venezuela, Suriname and Guyana). Accordingly, the actual number of countries selected for the application of the productivity shock in the model is 33.

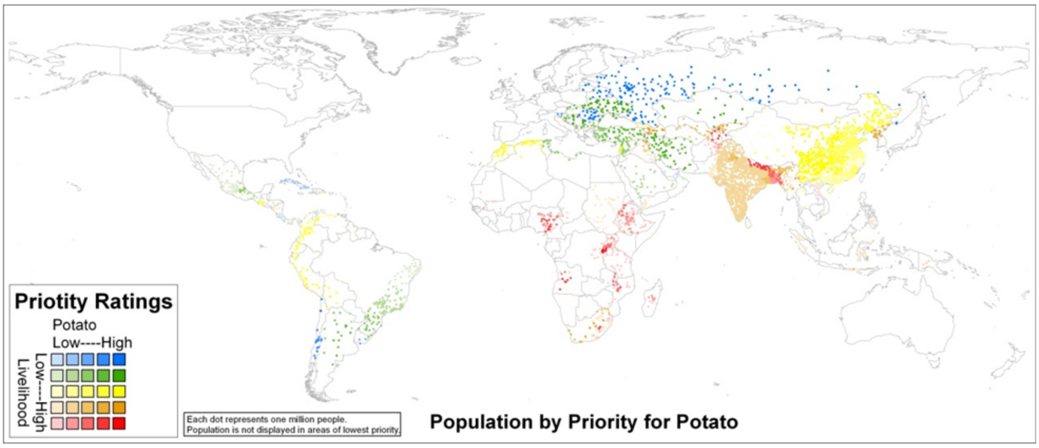

Figure 2: Population by priority for potato. Source: Theisen and Thiele (2008).

for the target countries as well as for the regions in which the countries are located. Columns 4 and 5 show the joint shares of the target countries in the totals of the regions and the world, respectively. Statistics are presented for the year 2000, which is the base year of the model simulation. Regional definitions follow the aggregations used by FAO (2012).

As the table shows, the target countries account for 35.5% of global potato production and 40.2% of food consumption. A look at the regions, however, reveals in parts substantially higher coverage. In Africa, the target countries account for 49.6% of total production, with particularly high coverage in Middle, Southern and Western Africa. While the target countries in the Americas represent only 16.9% of the total potato production of the bi-continent, the five target regions in South America make up 60.2% of the regional production. In Asia the coverage of the interventions accounts for 84.2% of the production of the continent, reaching up to 95.0% and 97.7% in Eastern and Central Asia, respectively.

The insights gained from these statistics allow formulating some first expectations about the effects of the simulated productivity shocks. First, as the simulated interventions cover slightly more than one third of worldwide potato production, the total impact will be somewhat watered down as compared to an intervention which would cover global production. The share of production affected, however, may well be large enough to produce a perceivable impact on global potato markets. Second, due to the substantially higher coverage in most developing regions and following the objective of agricultural research for development, the effects may be much stronger in these regions. It is, however, possible that the assumption of international tradability of the potato commodity and perfect global market integration

	Total amounts		Share target countries in regional totals	
	Production	**Food use**	**Production**	**Food use**
	(mio t)	*(mio t)*	*(%)*	*(%)*
World	**327.3**	**196.5**	**35.5**	**40.2**
Africa	**13.0**	**9.7**	**49.6**	**48.6**
Eastern Africa	**5.4**	**3.5**	**53.3**	**60.1**
Burundi	0.0	0.0	0.4	0.4
Ethiopia	0.4	0.3	7.2	9.3
Kenya	0.7	0.5	12.5	14.5
Rwanda	1.0	0.7	17.8	19.3
Uganda	0.5	0.3	8.9	9.3
Tanzania	0.4	0.3	6.5	7.3
Middle Africa	**0.3**	**0.3**	**57.4**	**41.2**
Angola	0.0	0.0	9.7	7.6
Cameroon	0.1	0.1	47.7	33.6
Northern Africa	**4.8**	**4.0**	**22.6**	**21.4**
Morocco	1.1	0.9	22.6	21.4
Southern Africa	**1.8**	**1.5**	**94.8**	**89.8**
South Africa	1.7	1.3	94.8	89.8
Western Africa	**0.7**	**0.5**	**87.9**	**68.6**
Nigeria	0.6	0.3	87.9	68.6
Americas	**42.1**	**31.8**	**16.9**	**16.7**
South America	**11.9**	**9.0**	**60.2**	**59.0**
Brazil	2.6	2.2	21.6	24.7
Bolivia & Paraguay	0.7	0.4	6.1	4.7
Ecuador	0.2	0.1	2.0	1.5
Northern South America	0.3	0.4	2.9	4.8
Peru	3.3	2.1	27.6	23.3
Asia	**121.4**	**85.7**	**84.2**	**80.5**
Central Asia	**3.9**	**2.5**	**97.7**	**97.0**
Kazakhstan	1.7	1.0	43.8	39.2
Kyrgyzstan	1.1	0.5	27.1	21.6
Tajikistan	0.3	0.2	7.9	9.3
Uzbekistan	0.7	0.7	18.9	26.9
Eastern Asia	**71.9**	**47.7**	**95.0**	**92.6**
China	66.3	42.8	92.3	89.8
North Korea	1.9	1.3	2.6	2.7
Mongolia	0.1	0.1	0.1	0.1
Southern Asia	**35.0**	**26.8**	**83.4**	**82.3**
Bangladesh	2.9	2.4	8.4	8.9
Bhutan	0.0	0.0	0.1	0.0
India	25.0	18.8	71.5	70.0
Nepal	1.2	0.9	3.4	3.3
South-Eastern Asia	**1.7**	**1.9**	**14.5**	**11.1**
Myanmar	0.3	0.2	14.5	11.1
Western Asia	**9.0**	**6.8**	**9.1**	**2.7**
Iraq	0.6	0.0	6.0	0.0
Lebanon	0.3	0.2	3.0	2.7

Table 1: Target regions for interventions, 2000. Source: FAO (2012), own calculations.

incorporated into the IMPACT model causes spillovers to non-target regions, which in turn weaken the effects in the countries of intervention.

Once defined the productivity shock and the target regions, two simulations are carried out. The first model run involves the simulation of the baseline scenario from 2000 to 2025 under the full set of standard assumptions built into the IMPACT-WATER model. Beside the baseline intrinsic growth rates for yields and areas as well as the standard set of demand and supply elasticities, this involves medium levels of population and GDP growth and no climate change (see Nelson et al., 2010). In the second simulation, 0.5 percentage points are added to the intrinsic yield growth rates in potato production in all target countries included in Table 1. In order to be in conformance with the time projections made by CGIAR (2011), this productivity shock is applied from the year 2011 onwards.

3 Results

3.1 Production Impacts

Table 2 presents the simulated development of potato production from 2000-2025 in selected target countries as well as at the level of macro-regions as defined by FAO. As the figures show, under the baseline assumptions potato production is estimated to increase in most countries and regions and in the world as a whole during the period under consideration. The exceptions to this generally positive trend are the group of industrialized countries as well as Malawi in Sub-Saharan Africa.

The most important factors in explaining the production growth observed in the majority of the countries are the yield and area changes. As Table 3 shows, until 2025 average yields increase in all regions except for Sub-Saharan Africa (SSA) in the baseline. Of the individual countries under consideration, only Ethiopia experiences yield declines. In the same period, area under potato production, in turn, increases in all regions of the developing world, with the notable exception of Malawi, and declines in the industrialized and transition economies (see Table 4). In case of the latter, the decline in production areas observed is mainly due to a reduction of cultivated areas in Russia, the major potato producer in this group of countries.

The four columns on the right hand side of Tables 2 to 4 present the estimated developments of production, yields and areas under a scenario with productivity growth rates, which in the selected target regions are 0.5% higher than under the baseline assumptions. According to Table 2, targeted interventions into potato production lead to a global crop which is by 1.3%

	Base		High productivity		% change high vs. base
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**135.45**	**205.54**	**135.45**	**212.60**	**3.4**
East Asia	**66.82**	**93.58**	**66.82**	**97.71**	**4.4**
East Asia minus China	4.47	6.19	4.47	6.35	2.6
China	62.35	87.39	62.35	91.36	4.5
South Asia	**29.52**	**50.30**	**29.52**	**52.61**	**4.6**
Bangladesh	2.97	6.58	2.97	6.96	5.8
India	23.49	38.63	23.49	40.42	4.6
Nepal	1.20	2.70	1.20	2.86	5.8
LAC	**16.32**	**24.41**	**16.32**	**24.77**	**1.5**
Bolivia & Paraguay	0.85	1.14	0.85	1.19	4.6
Ecuador	0.41	0.57	0.41	0.60	5.4
Peru	3.01	4.21	3.01	4.43	5.3
NENA	**15.90**	**27.45**	**15.90**	**27.4**	**-0.2**
SSA	**8.53**	**11.62**	**8.53**	**11.87**	**2.1**
Burundi	0.03	0.04	0.03	0.04	5.6
Ethiopia	0.39	0.55	0.39	0.56	1.0
Kenya	0.94	1.26	0.94	1.27	1.3
Malawi	2.24	2.21	2.24	2.18	-1.4
Rwanda	0.72	1.94	0.72	2.05	5.6
Uganda	0.48	1.11	0.48	1.15	3.5
Transition economies	**97.76**	**115.91**	**97.76**	**114.96**	**-0.8**
Uzbekistan	0.71	1.16	0.71	1.20	3.9
Industrialized countries	**80.83**	**78.37**	**80.83**	**77.64**	**-0.9**
World	**314.03**	**399.83**	**314.03**	**405.2**	**1.3**

Table 2: Estimated potato production 2000-2025, million metric tons.

	Base		High productivity		% change high vs. base
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**14.4**	**17.3**	**14.4**	**18.0**	**4.3**
East Asia	**13.4**	**15.9**	**13.4**	**16.7**	**5.2**
East Asia minus China	12.0	15.3	12.0	15.8	3.3
China	13.5	15.9	13.5	16.8	5.4
South Asia	**16.7**	**19**	**16.7**	**20.0**	**5.6**
Bangladesh	12.1	18.3	12.1	19.6	6.8
India	18.2	19.8	18.2	20.9	5.7
Nepal	9.7	14.5	9.7	15.5	6.7
LAC	**15.3**	**20.0**	**15.3**	**20.5**	**2.5**
Bolivia & Paraguay	6.5	7.4	6.5	7.8	6.0
Ecuador	8.4	8.8	8.4	9.3	6.7
Peru	11.4	14.1	11.4	15	6.7
NENA	**21.5**	**29.6**	**21.5**	**29.9**	**1.0**
SSA	**9.4**	**9.2**	**9.4**	**9.5**	**3.1**
Burundi	2.5	3.2	2.5	3.4	6.7
Ethiopia	7.3	6.8	7.3	6.9	2.0
Kenya	8.2	7.5	8.2	7.7	2.3
Malawi	12.2	13.1	12.2	13.1	-0.4
Rwanda	8.4	9.9	8.4	10.6	6.7
Uganda	7.0	9.0	7.0	9.4	4.6
Transition economies	**12**	**16.1**	**12.0**	**16.1**	**0.0**
Uzbekistan	14.0	18.5	14.0	19.4	4.5
Industrialized countries	**36.2**	**39.1**	**36.2**	**39.0**	**-0.1**
World	**15.9**	**18.9**	**15.9**	**19.3**	**2.2**

Table 3: Estimated potato yields 2000-2025, tons/ha, area weighted averages of irrigated and rainfed yields.

	Base		High productivity		% change high vs. base
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**9425**	**11899**	**9425**	**11796**	**-0.9**
East Asia	**4993**	**5886**	**4993**	**5840**	**-0.8**
East Asia minus China	371	405	371	402	-0.7
China	4622	5481	4622	5438	-0.8
South Asia	**1772**	**2654**	**1772**	**2628**	**-1.0**
Bangladesh	246	356	246	359	0.9
India	1291	1955	1291	1935	-1.0
Nepal	123	186	123	185	-0.9
LAC	**1065**	**1222**	**1065**	**1210**	**-1.0**
Bolivia & Paraguay	130	155	130	153	-1.2
Ecuador	49	65	49	64	-1.2
Peru	264	299	264	296	-1.2
NENA	**740**	**926**	**740**	**918**	**-0.8**
SSA	**910**	**1264**	**910**	**1252**	**-1.0**
Burundi	10	12	10	11	-1.0
Ethiopia	54	82	54	81	-1.0
Kenya	115	168	115	166	-1.0
Malawi	184	169	184	167	-1.0
Rwanda	85	195	85	193	-1.0
Uganda	68	123	68	122	-1.0
Transition economies	**8150**	**7221**	**8150**	**7161**	**-0.8**
Uzbekistan	51	62	51	62	-0.6
Industrialized countries	**2230**	**2007**	**2230**	**1990**	**-0.8**
World	**19806**	**21127**	**19806**	**20947**	**-0.9**

Table 4: Estimated area under potato production 2000-2025, thousand ha.

	Roots and tubers			**Grains**			**Livestock**		
	Potatoes	Cassava	Sweet potatoes & yam	Maize	Rice	Wheat	Beef	Pork	Poultry
World	**1.34**	**-0.02**	**-0.04**	**-0.01**	**-0.04**	**-0.04**	**0.00**	**0.00**	**0.01**
China	4.55	-0.02	-0.03	0.00	-0.04	-0.05	0.00	0.00	0.01
Bangladesh	5.84	na	-0.02	0.01	-0.04	-0.03	0.00	na	0.00
India	4.64	0.00	0.00	-0.01	-0.04	-0.04	0.01	0.00	0.00
Nepal	5.81	-0.01	na	0.00	-0.02	-0.04	0.01	0.00	0.00
Bolivia & Paraguay	4.64	-0.04	-0.02	0.00	-0.04	-0.04	0.00	0.00	0.00
Ecuador	5.41	-0.04	-0.02	0.00	-0.03	-0.04	0.00	0.00	0.00
Peru	5.33	-0.04	-0.02	0.00	-0.04	-0.04	0.00	0.00	0.00
Burundi	5.60	-0.01	-0.04	-0.02	-0.06	-0.06	0.00	0.00	0.00
Ethiopia	0.98	0.00	-0.03	-0.02	na	-0.06	0.00	0.00	0.00
Kenya	1.26	-0.01	-0.04	-0.02	-0.06	-0.06	0.00	0.00	0.00
Malawi	-1.40	-0.01	na	-0.03	-0.07	-0.08	0.00	0.00	0.00
Rwanda	5.63	-0.01	-0.04	-0.02	-0.06	-0.06	0.00	0.00	0.00
Uganda	3.54	-0.01	-0.04	-0.02	-0.06	-0.06	0.00	0.00	0.00
Uzbekistan	3.87	na	na	0.00	-0.03	-0.04	0.01	0.01	0.00

Table 5: Production of potatoes and non-target commodities by 2025 (% change high vs. base).

higher in 2025. In all target countries potato production is between 1.0% and 5.8% higher than under the baseline.

In terms of regions, the results make clear that the intervention in productivity would cause a further shift in potato production from industrialized countries and emerging economies towards the production regions of the developing world. While potato production in the former regions would be by 0.9% and 0.8% lower than in the baseline, respectively, it is by 3.4% higher in developing countries. Thereby, relative production increases would be highest in East and South Asia and more moderate in Latin America and the Caribbean and SSA. Potato production in the Near East and Northern Africa (NENA) would be lower than under the baseline. Yield increases in this region are insufficient to compensate for area reductions. At this, the observed shifts in production illustrate the effects of the technological interventions in the target regions: accelerated technological progress leads to lower production costs in the target countries and therefore to higher competitiveness of the potato producers in these regions.

Table 3 provides more detailed insight into the direct impact of the technology interventions on potato production. As the table shows, yields in the target countries in 2025 are, depending on the levels of the yield growth rates in the baseline, by between 2.0% and 6.8% higher in the scenario than under the baseline.[3] This translates into yield increases in the regions in which the respective countries are located by between 1.0% and 5.6%. Also, yields in countries and regions in which no interventions take place are lower in the scenario than in the baseline. Yields in Malawi, for example are 0.4% below baseline yields and the industrialized region has yields which are 0.1% lower. These declines in yields relative to the baseline illustrate the effect of lower producer prices, which make farmers grow their crop less intensively.

A further effect of higher increases in productivity is a reduction in potato production area by 2025 (Table 4). Across the globe, regional areas under the potato crop are by between -0.9% and -1.0% lower than without accelerated technological progress. This implies that farmers would be able to reduce the area farmed with potatoes, making land available for the cultivation of other crops.

The changes in production brought about by the high productivity scenario until the year 2025 presented in Table 5 illustrate the spill-over effects to a range of other commodities. Generally, the increase in potato production relative to the baseline leads to lower prices of potatoes and other commodi-

[3]The magnitude of the simulated difference in yields is inversely related to the size of the initial intrinsic yield growth rates. That is, countries with lower intrinsic yield growth rates exhibit stronger impacts of the technology intervention in percentage terms than countries with higher baseline rates.

ties (Table 12). These price effects in turn cause adjustments in production levels. As Table 5 shows, the cross-price effects are most pronounced for the better substitutes of potatoes, i.e. other roots and tubers and certain grains. In all countries under consideration, production of these crops is lower under the high productivity scenario. Although generally weak—by 0.01% to -0.08% of baseline production levels—the observed changes well point to a certain degree of substitution of potatoes for other crops. Livestock products appear to be much less affected, with production impacts visible only in a few cases. If present, however, these impacts are always positive, which is a consequence of lower prices for feed inputs into livestock production.

The case of Malawi, which is the only country in the list in which no intervention takes place, shows the different nature of the effects of the productivity increase on production structures in non-target countries. In these countries, due to the relatively strong decrease in producer prices for potatoes due to the productivity shock (Table 10), producers draw out of potato production rather than expanding it. As the decrease in production is stronger than in case of other commodities, a relative substitution of other commodities for potatoes takes place.

3.2 Impacts on Potato Demand

Tables 6 to 8 show the simulation results for total demand for potatoes, potato demand for food consumption and potato demand as animal feed from 2000 to 2025. According to Table 6, total demand for potatoes under the baseline increases in all individual countries under consideration, and in almost all regions as well as in the world as a whole during this period. As illustrated in Tables 6 and 7, this increase in demand over the two and a half decades happens due to rising food consumption demand for potatoes in the developing world and in industrialized countries. Feed demand increases in developing countries, but declines in the transition and industrialized economies. The baseline projections of the increases in demand for potatoes as food are explained by the continued population and income growth directly implemented in IMPACT. Further, they reflect trends of rising urbanization and changes in tastes and the desire of consumers to diversify their diets (Scott et al., 2000b).

The four columns on the left hand side of Table 6 show that total demand for potatoes is consistently higher under the scenario with the technology interventions in the target regions. Depending on the regions, the changes in demand range between 0.9% and 2.0%. These higher levels of demand as compared to the baseline are a response of consumers and feed users to the lower price levels brought about by the increases in productivity and

the consequently higher supply of potatoes. The differences between the regions in changes in potato demand, thereby, arise from regional differences in own price elasticities of potato demand as a principal factor as consumers in different regions respond more or less sensitively to a change in the potato price. The degree of this sensitivity roughly follows the gradient of income levels, with consumers in transition and industrialized economies showing the weakest reactions to price changes.

	Base		**High productivity**		**% change high vs. base**
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**138.67**	**221.72**	**138.67**	**225.43**	**1.7**
East Asia	**68.64**	**95.72**	**68.64**	**97.32**	**1.7**
East Asia minus China	5.60	8.61	5.60	8.74	1.5
China	63.04	87.11	63.04	88.58	1.7
South Asia	**29.60**	**60.09**	**29.60**	**61.22**	**1.9**
Bangladesh	2.97	5.38	2.97	5.49	2.0
India	23.45	48.7	23.45	49.61	1.9
Nepal	1.20	2.12	1.20	2.14	1.4
LAC	**17.27**	**24.64**	**17.27**	**24.94**	**1.2**
Bolivia & Paraguay	0.86	1.37	0.86	1.38	1.2
Ecuador	0.61	0.93	0.61	0.94	1.2
Peru	3.08	4.28	3.08	4.34	1.2
NENA	**16.62**	**26.06**	**16.62**	**26.5**	**1.7**
SSA	**8.17**	**17.20**	**8.17**	**17.47**	**1.6**
Burundi	0.03	0.06	0.03	0.06	1.9
Ethiopia	0.39	0.83	0.39	0.84	1.4
Kenya	0.94	2.13	0.94	2.17	1.9
Malawi	1.83	3.77	1.83	3.84	1.7
Rwanda	0.52	1.23	0.52	1.25	1.9
Uganda	0.48	1.47	0.48	1.50	1.9
Transition economies	**98.53**	**94.37**	**98.53**	**95.27**	**0.9**
Uzbekistan	0.77	1.09	0.77	1.10	1.1
Industrialized countries	**80.39**	**87.29**	**80.39**	**88.06**	**0.9**
World	**317.59**	**403.38**	**317.59**	**408.75**	**1.3**

Table 6: Estimated total demand for potato, 2000-2025, million metric tons.

The simulation results on potato demand once more illustrate that regionally limited interventions on the production side have global spillovers to other markets and regions. Mediated via a uniform world market price for potatoes, consumer prices in regions in which no intervention has taken place change are affected. Table 9 illustrates the spill-over effects on demand of other food commodities. Similar to production (Table 5), consumers react to relatively strong declines in potato prices and consume more of the crop at

	Base		High productivity		% change high vs. base
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**97.54**	**156.70**	**97.54**	**159.45**	**1.8**
East Asia	**43.89**	**60.55**	**43.89**	**61.67**	**1.9**
East Asia minus China	3.73	6.02	3.73	6.11	1.5
China	40.16	54.52	40.16	55.55	1.9
South Asia	**22.25**	**45.12**	**22.25**	**45.97**	**1.9**
Bangladesh	2.43	4.39	2.43	4.48	2.0
India	17.30	35.92	17.30	36.59	1.9
Nepal	0.9	1.57	0.9	1.60	1.4
LAC	**12.86**	**18.25**	**12.86**	**18.48**	**1.2**
Bolivia & Paraguay	0.55	0.87	0.55	0.88	1.2
Ecuador	0.47	0.72	0.47	0.72	1.2
Peru	1.85	2.58	1.85	2.61	1.2
NENA	**13.70**	**21.49**	**13.70**	**21.85**	**1.7**
SSA	**6.09**	**12.85**	**6.09**	**13.05**	**1.6**
Burundi	0.01	0.03	0.01	0.03	1.9
Ethiopia	0.32	0.69	0.32	0.70	1.4
Kenya	0.75	1.70	0.75	1.73	1.9
Malawi	1.27	2.70	1.27	2.74	1.7
Rwanda	0.39	0.94	0.39	0.96	1.9
Uganda	0.33	1.0	0.33	1.02	1.9
Transition economies	**42.18**	**41.69**	**42.18**	**42.08**	**0.9**
Uzbekistan	0.71	1.0	0.71	1.02	1.1
Industrialized countries	**54.96**	**60.96**	**54.96**	**61.51**	**0.9**
World	**194.68**	**259.36**	**194.68**	**263.03**	**1.4**

Table 7: Estimated food demand for potato, 2000-2025, million metric tons.

	Base		High productivity		% change high vs. base
	2000	**2025**	**2000**	**2025**	**2025**
Developing countries	**12.70**	**18.82**	**12.70**	**18.98**	**0.8**
East Asia	**12.01**	**17.78**	**12.01**	**17.93**	**0.8**
East Asia minus China	0.48	0.60	0.48	0.60	1.0
China	11.53	17.18	11.53	17.33	0.8
South Asia	**na**	**na**	**na**	**na**	**na**
Bangladesh	na	na	na	na	na
India	na	na	na	na	na
Nepal	na	na	na	na	na
LAC	**0.53**	**0.87**	**0.53**	**0.88**	**0.9**
Bolivia & Paraguay	0.06	0.10	0.06	0.10	0.8
Ecuador	0.03	0.04	0.03	0.04	1.1
Peru	0.09	0.09	0.09	0.09	1.0
NENA	**0.05**	**0.07**	**0.05**	**0.07**	**0.8**
SSA	**0.27**	**0.30**	**0.27**	**0.30**	**1.0**
Burundi	na	na	na	na	na
Ethiopia	na	na	na	na	na
Kenya	na	na	na	na	na
Malawi	na	na	na	na	na
Rwanda	na	na	na	na	na
Uganda	na	na	na	na	na
Transition economies	**26.50**	**23.96**	**26.50**	**24.21**	**1.0**
Uzbekistan	na	na	na	na	na
Industrialized countries	**5.10**	**4.37**	**5.10**	**4.42**	**1.1**
World	**44.30**	**47.16**	**44.30**	**47.61**	**1.0**

Table 8: Estimated feed demand for potato, 2000-2025, million metric tons.

	Roots and tubers			**Grains**			**Livestock**		
	Potatoes	Cassava	Sweet potatoes & yam	Maize	Rice	Wheat	Beef	Pork	Poultry
World	**1.42**	**-0.01**	**-0.07**	**-0.05**	**-0.04**	**-0.06**	**0.00**	**0.00**	**0.01**
	1.89	-0.09	-0.08	-0.06	-0.08	-0.08	0.00	0.00	0.01
Bangladesh	2.04	-0.05	-0.05	-0.09	-0.05	-0.05	0.00	0.00	0.01
India	1.87	-0.02	-0.02	-0.06	-0.05	-0.05	0.01	0.01	0.01
Nepal	1.37	-0.01	na	-0.11	-0.07	-0.08	0.00	0.00	0.01
Bolivia & Paraguay	1.21	-0.05	-0.05	-0.08	-0.04	-0.06	0.00	0.01	0.01
Ecuador	1.24	-0.06	-0.05	-0.08	-0.04	-0.06	0.00	0.01	0.01
Peru	1.24	-0.06	-0.04	-0.08	-0.04	-0.06	0.00	0.01	0.01
Burundi	1.94	-0.08	-0.09	-0.04	0.01	0.00	0.01	0.01	0.01
Ethiopia	1.42	-0.01	-0.04	-0.02	0.04	0.03	0.01	0.01	0.01
Kenya	1.88	-0.08	-0.09	-0.04	0.01	-0.01	0.01	0.01	0.01
Malawi	1.70	-0.02	na	-0.01	0.03	0.03	0.01	0.01	0.01
Rwanda	1.89	-0.08	-0.10	-0.04	0.01	-0.01	0.01	0.01	0.01
Uganda	1.93	-0.08	-0.10	-0.04	0.01	-0.01	0.01	0.01	0.01
Uzbekistan	1.13	na	na	-0.02	0.02	0.00	0.00	0.00	0.01

Table 9: Food demand for potatoes and non-target commodities by 2025 (% change high vs. base).

the expense of other crop products. Interestingly, in the African countries as well as in Uzbekistan the stronger productivity growth in potatoes leads to slightly higher levels of rice consumption. This is a result of comparatively low cross-price elasticities of rice demand in the price of potatoes in these countries.

As in case of production, food consumption of livestock commodities is positively affected. These commodities benefit from slightly lower consumer prices without being subject to cross-price effects in the potato price, thus arriving at slightly higher levels of consumption. Again, however, the differences to the baseline scenario are only marginal.

3.3 Impacts on Prices and Trade

Tables 10 to 13 present the simulations results on prices and trade. As shown in the first three columns of Tables 10 and 11, the period under consideration is characterized by increases in producer and consumer prices for potatoes in all regions of the world and all countries under consideration. This rising trend is a result of the well known factors which are expected to shape the development of agricultural markets throughout the coming decades: economic growth, rising incomes, population growth and rising demand for agricultural commodities for non-food uses, along with relatively weak growth in production. This is not only true for potato prices, but also for the prices of other crops and livestock commodities (Table 12).

The four columns on the right hand sides of Tables 10 and 11 illustrate the development of producer and consumer prices under the scenario with higher productivity in potato production. It becomes evident that the technology interventions remove some pressure from the market by reducing producer and consumer prices in all countries under consideration by 2.2%. Thereby, the reduction in prices is uniform across all countries and corresponds to the change in the world market price for potatoes.

As Table 12 shows, depending on the degree of substitutability in consumption, world market prices for other commodities are affected, as well. Prices for other roots and tubers are by 0.2% lower than under the baseline. Prices for grains are reduced by 0.1%. Prices for protein crops (soybeans) or livestock are less affected. As in case of potatoes the producer and consumer prices for all the commodities shown change accordingly in all countries.

Regional changes in productivity and the associated effects of prices, consumption and production lead to changes in trade patterns (Table 13). Without the technology interventions, East Asia would slightly increase its net imports between 2000 and 2025. This trend would be reversed by the projected increase in potato productivity in the region. In particular due to the

	Base		**High productivity**		**% change high vs. base**
	2000	**2025**	**2000**	**2025**	**2025**
East Asia					
China	149.25	172.44	149.25	168.70	-2.2
South Asia					
Bangladesh	149.25	172.44	149.25	168.70	-2.2
India	149.25	172.44	149.25	168.70	-2.2
Nepal	149.25	172.44	149.25	168.70	-2.2
LAC					
Bolivia & Paraguay	149.25	172.44	149.25	168.70	-2.2
Ecuador	149.25	172.44	149.25	168.70	-2.2
Peru	149.25	172.44	149.25	168.70	-2.2
SSA					
Burundi	106.61	123.17	106.61	120.50	-2.2
Ethiopia	106.61	123.17	106.61	120.50	-2.2
Kenya	106.61	123.17	106.61	120.50	-2.2
Malawi	106.61	123.17	106.61	120.50	-2.2
Rwanda	106.61	123.17	106.61	120.50	-2.2
Uganda	106.61	123.17	106.61	120.50	-2.2
Transition economies					
Uzbekistan	127.93	147.81	127.93	144.60	-2.2

Table 10: Estimated producer prices for potato, 2000-2025, US$ constant 2000/mt.

	Base		**High productivity**		**% change high vs. base**
	2000	**2025**	**2000**	**2025**	**2025**
East Asia					
China	277.19	320.25	277.19	313.29	-2.2
South Asia					
Bangladesh	277.19	320.25	277.19	313.29	-2.2
India	277.19	320.25	277.19	313.29	-2.2
Nepal	277.19	320.25	277.19	313.29	-2.2
LAC					
Bolivia & Paraguay	277.19	320.25	277.19	313.29	-2.2
Ecuador	277.19	320.25	277.19	313.29	-2.2
Peru	277.19	320.25	277.19	313.29	-2.2
SSA					
Burundi	319.83	369.52	319.83	361.49	-2.2
Ethiopia	319.83	369.52	319.83	361.49	-2.2
Kenya	319.83	369.52	319.83	361.49	-2.2
Malawi	319.83	369.52	319.83	361.49	-2.2
Rwanda	319.83	369.52	319.83	361.49	-2.2
Uganda	319.83	369.52	319.83	361.49	-2.2
Transition economies					
Uzbekistan	298.51	344.88	298.51	337.39	-2.2

Table 11: Estimated consumer prices for potato, 2000-2025, US$ constant 2000/mt.

	Base		High productivity		% change high vs. base
	2000	2025	2000	2025	2025
Roots and tubers					
Potato	213.22	246.34	213.22	240.99	-2.2
Cassava	64.03	83.62	64.03	83.47	-0.2
Sweet potato/yams	481.92	614.08	481.92	613.04	-0.2
Grains					
Maize	89.43	118.13	89.43	118.07	-0.1
Rice	207.87	262.59	207.87	262.31	-0.1
Wheat	115.10	152.64	115.10	152.50	-0.1
Sorghum	89.97	135	89.97	134.92	-0.1
Other grains	71.07	82.37	71.07	82.32	-0.1
Soybean	186.19	250.85	186.19	250.76	0.0
Livestock					
Beef	1968.0	2458.87	1968.0	2458.61	0.0
Pork	899.33	1106.93	899.33	1106.81	0.0
Poultry	1231.31	1583.75	1231.31	1583.47	0.0

Table 12: Estimated world market prices, selected commodities, 2000-2025, US$ constant 2000/mt.

increase in potato production and exports in China, the region would turn itself into a net exporter of potatoes. Similarly, South Asia would slightly reduce its net imports in potatoes.

In Latin America and the Caribbean, the countries in which the interventions took place reduce their net imports (Bolivia and Ecuador) or shift from being net importers to net exporters of potatoes (Peru). Overall, this leads to a doubling of regional net exports, albeit at a low level.

The countries of the NENA are expected to experience a strong increase in net exports under the baseline. This increase is somewhat dampened under the high productivity scenario due to the higher consumption levels which go hand in hand with lower levels of production.

As a consequence of the pronounced increases in demand, SSA is predicted to strongly increase net imports under the baseline. Thereby, it is surprising at the first sight that the interventions in potato production in spite of the production increase would cause increases in net imports in case of three of the six countries under consideration. This, however, is a consequence of relatively strong consumption effects of the decline in consumer prices of potato.

The developing countries as a whole, which would become strong net importers of potatoes under the baseline, would become less so if the pro-

	Base		High productivity	
	2000	**2025**	**2000**	**2025**
East Asia	**-1.59**	**-1.91**	**-1.59**	**0.62**
East Asia minus China	-0.99	-2.27	-0.99	-2.24
China	-0.61	0.35	-0.61	2.86
South Asia	**0.01**	**-9.70**	**0.01**	**-8.52**
Bangladesh	0.00	1.20	0.00	1.48
India	0.04	-10.07	0.04	-9.19
Nepal	-0.01	0.59	-0.01	0.72
LAC	**-0.66**	**0.06**	**-0.66**	**0.12**
Bolivia & Paraguay	-0.01	-0.23	-0.01	-0.19
Ecuador	0.01	-0.16	0.01	-0.14
Peru	-0.07	-0.07	-0.07	0.10
NENA	**0.01**	**2.06**	**0.01**	**1.68**
SSA	**-0.10**	**-6.05**	**-0.10**	**-6.07**
Burundi	0.00	-0.02	0.00	-0.02
Ethiopia	0.00	-0.28	0.00	-0.28
Kenya	0.00	-0.87	0.00	-0.89
Malawi	0.00	-1.97	0.00	-2.07
Rwanda	0.00	0.51	0.00	0.59
Uganda	0.00	-0.36	0.00	-0.35
Developing countries	**-2.35**	**-15.31**	**-2.35**	**-11.97**
Transition economies	**-0.41**	**21.90**	**-0.41**	**20.07**
Uzbekistan	-0.06	0.07	-0.06	0.11
Industrialized countries	**2.76**	**-6.60**	**2.76**	**-8.10**

Table 13: Estimated net trade in potatoes, 2000-2025, million metric tons.

ductivity interventions were to be implemented. The transition economies and the industrialized countries, in turn, would have lower net exports and higher net imports, respectively. This once more points to the shift in production of potato towards the developing world due to the increase in potato productivity in that region.

3.4 Food Security Impacts

An important aspect of any intervention from agricultural research for development is the impact on food security. The effects of the productivity change in potato production in the target countries on the daily availability of calories per capita and the percentage of malnourished children are summarized in Table 14. The table shows the values of the respective indicators by the year 2025 for both scenarios. Regarding the availability of calories per capita, the intervention would have positive impacts for most of the countries under consideration. This impact, however, is only marginal, reaching at most four additional calories per day, which would reflect an increase by 0.18% against the baseline.

	Calories/capita			**Percentage malnourished children**		
	Base	**High**	**Change** (%)	**Base**	**High**	**Difference** (% points)
China	3378	3378	0.01	2.46	2.46	0.00
Bangladesh	2140	2140	0.00	49.37	49.37	0.00
India	2514	2514	0.01	40.72	40.72	0.00
Nepal	2349	2349	-0.02	42.78	42.79	0.00
Bolivia & Paraguay	2345	2345	0.02	17.12	17.12	0.00
Ecuador	2634	2635	0.01	16.42	16.42	0.00
Peru	2413	2415	0.08	4.82	4.80	-0.02
Burundi	2000	2000	-0.02	41.95	41.95	0.01
Ethiopia	2005	2005	0.01	44.41	44.41	0.00
Kenya	2208	2209	0.03	13.23	13.22	-0.01
Malawi	1951	1955	0.18	29.20	29.15	-0.04
Rwanda	2086	2089	0.13	23.96	23.92	-0.03
Uganda	3250	3250	0.00	16.34	16.34	0.00
Uzbekistan	2804	2805	0.03	18.28	18.27	-0.01

Table 14: Food security indicators by 2013.

Similarly, the productivity enhancement would lead to only marginal reductions in the percentage of malnourished children. While in about half of the countries no impact at all is visible, the reductions against the baseline

	Roots and tubers			**Grains**			**Livestock**		
	Potato	Cassava	Sweet potato/ yam	Maize	Rice	Wheat	Beef	Pork	Poultry
China	1.87	0.00	-0.07	-0.05	-0.09	-0.09	0.00	0.00	0.00
Bangladesh	2.05	0.00	-0.43	-0.14	-0.05	-0.06	0.00	na	0.00
India	1.87	0.00	0.00	-0.06	-0.06	-0.06	0.00	0.00	0.00
Nepal	1.40	0.00	na	-0.10	-0.06	-0.06	0.07	0.00	0.00
Bolivia & Paraguay	1.22	-0.06	-0.15	-0.10	-0.06	-0.08	-0.02	-0.03	0.00
Ecuador	1.22	0.00	0.00	-0.07	-0.05	-0.07	-0.02	0.00	0.00
Peru	1.16	-0.13	-0.19	-0.15	-0.12	-0.14	-0.14	0.00	-0.06
Burundi	1.94	-0.08	-0.09	-0.04	0.01	0.00	0.01	0.01	0.01
Ethiopia	1.38	-0.02	0.00	-0.03	0.00	0.03	0.00	0.00	0.00
Kenya	1.84	-0.09	-0.14	-0.07	-0.04	-0.04	-0.04	0.00	0.00
Malawi	1.53	-0.19	na	-0.19	-0.15	-0.15	-0.24	-0.17	0.00
Rwanda	1.77	-0.21	-0.23	-0.16	-0.10	-0.15	-0.14	0.00	0.00
Uganda	1.93	-0.08	-0.10	-0.05	0.00	0.00	0.10	0.00	0.00
Uzbekistan	1.09	na	na	0.00	0.00	-0.03	-0.03	0.00	0.00

Table 15: Share of contribution of calories by commodity to average diet by 2025 (% change against baseline).

amount to 0.04 percentage points, at most.

An interesting observation is that in case of Nepal and Burundi, the availability of calories declines slightly with the intervention. This result is related to the cross-price effects of the intervention on the consumption of other commodities: the relatively strong decline in consumer prices for potatoes causes consumers to shift away from the consumption of other food commodities. In case of Burundi, sweet potato and cassava are particularly strongly affected, while in Nepal consumers reduce the consumption of maize, rice and wheat. Since these commodities make up rather high shares of the food consumption baskets in the two countries, the overall impact of the productivity changes on calorie intake becomes slightly negative.

More generally, the effects found in case of Burundi and Nepal also explains the overall weak impact of the higher productivity in potato production on food security: consumers not only eat more potatoes, which should increase the calorie intake, but at the same time substitute away from the consumption of other food products, thus adding a counteracting effect. In the consequence, the per capita amount of calories available may well remain largely constant.

Table 15 illustrates more in detail that the productivity shock not only leads to changes in the overall calorie availability, but also in the sources of food calories, i.e. the composition of the diet. As the table shows, under the high productivity scenario potatoes would increase their share in calories consumed by between 1.09% and 2.05% in the countries under consideration by 2025. The contribution of other food commodities, in turn, is reduced.

Beyond the availability of energy from food, however, the nutrient composition of the diet is a further important dimension of food security. With this respect, the results indicate that potatoes are substituted for grains, which due to a relatively high micronutrient content of potatoes as compared to grains could be considered favorable. On the other hand, as the intake of meat and other roots and tubers is also reduced, the nutrition outcome may be ambiguous. Moreover, the overall small changes raise the question whether the changes would have a significant impact on the nutritional status of the population, at all. Certainly, more research is indicated here.

4 Summary and Conclusions

The model simulations presented and discussed in this paper allow assessing the global effects of an increase in the growth rate in potato productivity by 0.5% over baseline growth in selected target countries. If effective from 2011 onwards, the interventions would lead to higher production in potatoes in the

target regions and for the world as a whole. This would be a consequence of higher yields in these regions, and go hand in hand with reductions in production areas. Thereby, spillovers to other regions and commodities can be observed. In non-target regions potato production would decline. This would be a result not only of area contractions, but also of reductions in yields, driven by lower prices. Likewise, the production of other crops would be negatively affected, whereas livestock production would remain unaffected or benefit.

A direct consequence of higher production levels due to the technology intervention would be lower world market prices. National levels of producer and consumer prices as well as the prices for other crop commodities would also be lower. Higher production and lower prices for potatoes would lead to a globally higher demand for potatoes, in target and non-target regions alike. Food demand for other crop products would see itself somewhat negatively affected; consumption of livestock products would rise, albeit by low margins. The global shifts in potato production are also reflected in altered trade patterns. Patterns of net trade would change slightly towards lower net imports or higher net exports of regions in which the target countries are located.

In terms of food security, increased yield growth in potato production would produce weakly positive effects. In most of the countries under consideration, a slightly higher per capita availability of calories would lead to reductions in the share of malnourished children. These effects, however, are found to be only very weak and might not be significant.

In spite of the weak effect in terms of food security, the simulations clearly show that targeted interventions in potato productivity would have visible and perceivable impacts. Although the geographic and commodity coverage of the simulated interventions is limited, impacts transcend the target countries and become global, extending to other countries, regions and markets.

Thereby, some lessons can be drawn from the qualitative nature of the observed impacts on production, consumption and prices. Generally, the lower levels in prices of potatoes and other commodities benefit consumers worldwide. This positive effect, although comparatively low in magnitude, may be long lasting, and therefore unfold potentially significant welfare implications in terms of additional consumer surplus.

In case of producers, the assessment is less straightforward. Potato producers in target areas who have access to the technological innovations may be able to counter the price decreases by higher productivity and lower cost of production. For potato producers in non-intervention countries, however, the interventions would represent a burden, as they are only hurt by lower prices for their produce without being able to benefit from improved produc-

tion technologies. Similarly, producers of other crops may also be somewhat negatively affected. Livestock production will feel mixed impacts from lower output prices on the one hand and reduced input costs on the other hand.

This analysis points to the complexities associated an assessment of the welfare effects of the simulated interventions. First, positive effects for the target population may entail negative consequence for non-target populations. Second, agricultural producers, in particular the poor, may hardly be specialized in potato production alone. Hence, they will also be affected by impacts of the intervention on other commodities. In a similar manner, the target populations of agricultural research for development may best be characterized as producer-consumer households, for which the ultimate welfare outcome is determined by the interplay of changes on the production and the consumption side (Singh et al., 1986). This calls for a comprehensive calculation of consumer and producer surplus based on the supply and demand functions of the IMPACT model on the one hand and for complementary micro-simulation exercises which adequately capture the conditions of the agricultural household on the other hand.

When assessing the simulation results, one should also bear in mind a number of aspects which characterize potato production and consumption and which may not be adequately reflected by the IMPACT model and hence affect the results. A first of these aspects is the fact that the current spatial disaggregation of IMPACT yields a relatively aggregate picture of supply and demand. In particular, figures on production and consumption represent the average situation at the level of the 115 IMPACT regions. This aggregate view neglects that potato production and consumption (just as in case of roots and tubers in general) may in cases be disproportionately concentrated among the poor. At this, the role of potato as a food security crop in many countries is of particular importance. This role of potato for the poor and food insecure may imply that the actual benefits from productivity increases in potato production which accrue to these groups may be higher than simulated. A higher spatial disaggregation of the simulation units on the supply and the demand side in the model would constitute a step forward here.

A second aspect concerns the depiction of potato production in the model. IMPACT represents production by simple area and yield functions at the FPU level. In developing countries, however, potato production often is for subsistence purposes, with correspondingly high shares of self-consumption and the consequence that the crop is largely nontraded. This may imply supply responses of potato producers to price changes that are weaker than simulated and would have the consequence of weaker reductions in supply in developing countries not targeted by the intervention and consequently stronger price impacts in the scenario. As a first step towards taking this

into account, the supply elasticities in the model should be reviewed and their reliability assessed.

Related to this aspect is the modeling of potato in IMPACT as a traded commodity with a single world market price and perfect international price transmission. This assumption contrasts with the largely nontraded character of the commodity. If potatoes were modeled as nontraded, price transmission would be weaker and a stronger regional differentiation of price levels could be observed. This would have implications for the distribution of the effects of the productivity shock across the globe. While rather evenly distributed in the present simulation, effects might actually be stronger in target regions and weaker in non-target regions. Given that this aspect is valid for other roots and tubers, as well, it will be worthwhile to assess the implications of modeling potato as a nontraded commodity for the model results.

The studies by Scott et al. (2000a,b) also highlight a rising importance of processing in the use of potatoes for food, not only in industrialized countries but also in the developing world. Developments in this area may have implications for supply and demand alike and would merit an inclusion of a potato processing sector into IMPACT. As in case of nontradability, this would also contribute to an improved depiction of other roots and tubers for which processing also plays an increasingly important role.

Finally, the discussions of the results on food security indicate that while the overall amount of per capita calorie intake may not vary much with an intervention, the composition of the diet may change. Hence, a better representation of nutritional aspects for the food security analysis will provide a more accurate picture of food security impacts.

Apart from the technical aspects of the modeling of potatoes in IMPACT, the simulated scenario—a highly stylized one—offers scope for refinement. The envisaged rise in yield growth rates by 0.5% over baseline growth may be overly ambitious in case of some countries. In case of others, even higher growth rates might be possible, all depending on the infrastructure and the presence of organizations which can promote and disseminate the results of public research in the target regions. Similarly, the incorporation of adoption pathways will provide a more realistic picture and a better temporal resolution of the impacts of the interventions. Incorporating more expert knowledge is indicated at this point.

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