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Potato and Tomato Supply and Yield Responses to Policy in Ethiopia

Zewdie Habte Shikur†

Abstract

Improving the productivity and profitability of farming activity is considered the key pathway out of poverty for many rural households. Agricultural productivity can be achieved through improving technical progress and increasing irrigation practice utilization. The motivation of this study is to figure out the underlying reasons for the low inelastic potato and tomato supply responses in the short and long-run. The paper attempts to estimate the responsiveness of potato and tomato yield and supply to demand, irrigated area, technical progress and industrial policy in Ethiopia. The study uses the error correction model and VARs with the aid of time series data. The results indicate that tomato supply is found to be responsive to demand signal and industrial policy shock in the short run but not to price incentive in the short-run as predicted. Tomato yield is responsive to demand signal, price incentive and industrial policy shock in the short-run. The numerical magnitude of error correction coefficient for potato yield is 0.88 indicating about 88% of disequilibrium is corrected in a year. The implied departure from equilibrium is about 12%. Interventions in increasing irrigated area and the technical progress in potato and tomato production impact yield and output significantly. The speeds of adjustment towards equilibrium for tomato yield and output are quite fast, it points towards the highest response to technical progress. The results give emphasis to the need to strengthen technical progress and irrigation water supply through effective policies.

Keywords: Production; potato and tomato yields; and outputs responses; irrigation practice; technical progress
JEL Classification Codes: Q11, Q15, Q16, Q18

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† Department of Agricultural Economics, Wolaita Sodo University, Author Email Address: zewde91@gmail.com

1. Introduction

Ethiopian agriculture provides about 38.8% of gross domestic product (GDP), about 80% of the total value of its exports, and about 75% of the raw material requirements (NBE, 2016/17). Agriculture is also a source of livelihood for more than 83.4% of people in the country. However, like developing countries, the supply of arable land in Ethiopia is inelastic due to population growth (Torkamani, 2005). Population pressure and poor farming practice result in poor factor productivity which leads to stagnant and declining food production (Yao, 1996). The agricultural sector is also characterized by an inelastic supply of outputs (Schiff &Montenetgro, 1995). As a result, people face deficiencies in food production (Diamond, 2005). Obtaining higher productivity is the major way of increasing agricultural food supply and reducing food shortage (Irz & Tiffin, 2006; Fan, 2008; Loayza & Raddatz, 2010; Benin, 2016). Tomorrow's farmers need to increase farm productivity to harvest more food with less land (Schneider et al., 2011).

Agricultural productivity can be achieved through improving technical progress and increasing irrigation water supply (Schneider et al., 2011; Shoko et al, 2016). Without technical progress and with current rates of population growth, agriculture would need an area equivalent to one-half and two-thirds of the current terrestrial land area by 2030 and 2070 respectively, in order to maintain current food consumption levels per capita (Schneider et al., 2011). The improved agricultural technology increases the productivity of resources like labor and land (Torkamani, 2005). Agricultural resource productivity creates new jobs in non-agricultural, rural, and service industries and raises national income (Mellor, 1983), and improves food supply (Schneider et al., 2011). Improving the productivity and profitability of farming activity is considered the key pathway out of poverty for many rural households (Christiaensen et al., 2011; Collier & Dercon, 2014; Diao et al., 2010). Therefore, agricultural policy interventions need to give emphasis to encourage the adoption of bio-chemical technology to increase agricultural productivity growth (Ravallion & Datt, 1999; Gollin et al., 2002; Thirtle et al., 2003; Irz & Tiffin, 2006; Fan, 2008; Benin, 2016). To design future agricultural policies, policymakers need insights into the way these policy interventions encourage farmers' input use and modify farmers' rates of technical knowledge usage. The extent to which these policy interventions will affect farmers' economic efficiency and productivity is an interesting policy issue.

Although few the studies provide evidence on the effects of policy shock and market incentives on agricultural supply response (e.g., Dercon & Lulseged, 1994; Zerihun, 1996; Abrar et al., 2003; Alemu et al., 2003), research that explains specific policy interventions considering only potato and tomato yield and output responses as well as using time series data is still scant in the developing countries like Ethiopia. This paper fills the knowledge gap that exists in developing countries like Ethiopia on how policy shocks affect potato and tomato yield and output responses. The paper contributes to the literature by studying tomato and potato yield and supply responses to industrial policy in Ethiopia. Analysis of the effect of industrial policy on supply and yield responses can give useful information that can assist to address the lowest potato and tomato productivity and production in Ethiopia. Even though the analysis of the issue provides valuable information for policymakers, the earlier empirical studies investigating this issue are very inadequate. The findings could help redress Ethiopian lowest productivity among potato-producing African countries as the central aim of a policy issue in potato and tomato farming, the topic which was ignored in Ethiopia. Besides, the paper can provide the latest, accurate, and reliable information about yield and supply response to policy intervention in Ethiopia.

This information on potato and tomato yield and output responses in Ethiopia may support policymakers to improve the allocation of resources. Thus, the method of the analysis is adequately comprehensive to give enough and correct information about the consequences and desirability of policy interventions on potato and tomato yield and output responses. It is often assumed that greater potato and tomato yield and output responses could arise from applying better rates of technical knowledge usages and more irrigated areas to the same land during dry and wet seasons. The paper examines the effects of simulated technical progress and irrigated area on potato and tomato yield and output responses using nationally representative time-series datasets from Ethiopia.

The rest of the paper is organized as follows. The second sections present background that focuses on the conceptual framework and the simulations about technical progress and irrigated area. The third section gives a brief description of the data and model specifications. The fourth section presents the results. The last section then draws some of the policy implications.

2. Background

Potato is the world's fourth-largest food crop next to rice, wheat, and maize that have a positive impact on stability in food supply and socioeconomics. In general, potato needs intensive irrigation, fertilization, and frequent pesticide applications to achieve the highest yields possible. Potato productivity highly depends on modern biotechnology which has a significant impact on reductions in production cost (Halterman et al., 2016). The biotech potato significantly increases productivity and reduces costs of production. However, the current average potato yield is low in Sub-Saharan Africa. This yield gap can be attributed to the use of low-quality seed potatoes, low-yielding varieties, and poor disease management (Olanya et al., 2001; Tessema & Dagne, 2018). Algeria, Egypt, and South Africa are the top potato-producing countries in Africa and they also import a substantial amount of potato seeds. Potato yield per hectare is the highest in Algeria. The average potato yield increased 7.13 tonnes in 1961-1980 to 11.05 tonnes in 1981-2000 and to 25.68 tonnes in 2000-2018 in Algeria due to the adoption of the improved varieties, and modern agricultural techniques. The average potato yield was 31.11 tonnes in 2018 which was the highest among the top potato-producing countries (Table 1). The rise in potato yield has been achieved through the adoption of new improved varieties, new production techniques, agricultural mechanization, and modern irrigation techniques, and the remaining per cent increase in yield has been attributed to planting area expansion. Algeria, Egypt, and Morocco are top seed potato importing countries in Africa (Kees, 2007). Egypt is the second-largest potato-producing country next to Algeria in Africa. Table 1 clearly showed that Ethiopian potato yield was the lowest among the four listed potato producing countries due to a lack of seed potato technological advances, lack of disease-free and clean seed, and poor quality seeds/inputs delivery systems (Tessema & Dagne, 2018) which result in big potato yield gap. The average potato yield in Ethiopia increased from 1.21 tonnes in 1981-2000 to 1.94 tonnes in 2001-2018. The big yield gap implies that Ethiopia has a huge potential to increase potato production.

Table 1: **Potato yield and supply in selected potato-producing countries in Africa**

Country	Period	Area harvested (hectare)	Potato yield (ton)	Potato supply (ton)
Algeria	1961-1980	47780.00	7.13	329687.80
	1981-2000	87731.00	10.37	890569.40
	2000-2018	117389.00	25.68	3123855.00
	2018	149665.00	31.11	4653322.00
Egypt	1961-1980	37108.60	16.51	613921.20
	1981-2000	80150.35	20.78	1672476.00
	2000-2018	136617.40	25.89	3575764
	2018	174311.00	27.72	4896476.00
Ethiopia	1961-1980	31485.00	8.00	251880.00
	1981-2000	46693.75	7.91	362794.60
	2000-2018	60966.89	10.25	628897.60
	2018	66933.00	11.10	743153.00
South Africa	1961-1980	46670.70	12.10	558000.00
	1981-2000	59846.25	21.23	1252776.00
	2000-2018	59303.72	34.28	2020944.00
	2018	68277.00	36.43	2467724.00

Source: Faostat database, 2020.

Crop yield responses to irrigation water supply (Doorenbos and Kassam, 1979). Technical changes significantly increase the crop yield and supply (Kanwar, 2006; FAO, 2009; Schneider et al., 2011; Le Clech and Fillat-Castejón, 2017; Gupta et al., 2018). The low price elasticity of the crop supply could be due to the lack of technical changes which reduce the farmers' ability to respond to changes in the prices and demand (Bloom and Sachs, 1998). Key et al (2000) argued that the vegetable supply reacts to exogenous market price changes. Vegetable supply in the market is inversely related to prices. When the vegetables are scarce in the markets and their prices are high, farmers increase production in the next season (Mendoza, 1995; Emana & Gebremedihin, 2007). The subsequent excess supply in the next production cycle lowers the market price and farmers decrease production in the subsequent season. The scenarios include specifically simulated potato and tomato yields and outputs, technical progress, and irrigated area. The simulated model explicitly depicts the relationship between the simulated potato yields and simulated factors such as irrigated area and technical progress.

Many scholars suggest governments in developing countries to focus on productivity improvement, through public investment in irrigation, research, and other inputs for the long term (e.g., Fan et al., 1999; Evenson et al., 1999). For the scenario irrigated area, it is assumed that increased irrigated area shifts the potato and tomato supply curves downward to the right. In the scenario, however, the irrigated area is influenced by an increase in the availability of groundwater and river basin. For this scenario, it is assumed that the irrigated area over time increases by 4% relative to the year 1993. Management-specific potato and tomato technical progresses and their specific irrigated areas are simulated on the basis of research results conducted by Awulachew et al. (2010) & Desta et al (2017). Agricultural policy and strategic interactions increase the technical knowledge which has a significant effect on yield (Shoko et al., 2016, Shikur et al., 2020). Technological change is a principal deriver of productivity growth (OECD 2012; Morris et al. 2007; DFID, 2006; Shikur, 2020). Agricultural productivity improvement is the primary policy to initiate the agricultural transformation (Alvarez- Cuadrado & Poschke 2011; Ngai & Pissarides 2007) and increase food supply in the economy. Technical progress refers to an improvement in the instructions for mixing together raw materials which are fundamental for productivity growth (Romer, 1990). The second scenario is based on technical change over time which is constructed based on specific technical efficiency on historical trends from 1993 till 2018. The scenario concerns the impact of an increase in the technical change, simulated by a 5 per cent increase in efficiency or technology over time (i.e. the study assumes that change in technology dividing by change in time is 5 per cent), holding other factors constant. Potato and tomato modeling can be used as a decision tool for increase irrigation practices, and quantity of fertilization and utilization quality seed which can help to increase yield potato and tomato crop can be efficiently and easily done by the adoption of the superior method of production.

4. Research Methodology

The data on annually potato and tomato prices, demands, outputs and yields are used in order to investigate the potato and tomato yield and output responses in Ethiopia. Demand data are the function of observed price, per capita income and population growth. Data on prices of potato and tomato outputs, per capita income and population growth are obtained from Faostat database (2018). Specifically, the data cover the period from 1993 to 2018. Potato production data refer to the actual harvested production from the field, excluding harvesting and threshing losses and that part of crop not harvested for any reason. Production therefore includes the quantities of the commodity sold in the market (marketed production) and the quantities consumed or used by the producers (auto-consumption). Potato and tomato production data are measured in metric tons (MT). Data refer to the area from which a crop is gathered. Area harvested, therefore, excludes the area from which, although sown or planted, there was no harvest due to damage, failure, etc. If the crop under consideration is harvested more than once during the year as a consequence of successive cropping (i.e., the same crop is sown or planted more than once in the same field during the year), the area is counted as many times as harvested. On the contrary, area harvested will be recorded only once in the case of successive gathering of the crop during the year from the same standing crops. Area harvested is recorded in hectares (HA).

Household food demand has been primarily determined by growth in population and per capita income (Cirera & Masset, 2010; Schneider et al., 2011; Mittal, 2014). In this study, the potato and tomato demand are specified as a function of price, per capita income and growth in population. Demand for potato and tomato is written in equation 1 as:

$$Qd_t = \alpha + \beta_1 P_t + \beta_2 Popg_t + \beta_3 PCI_t + \varepsilon_t \tag{1}$$

Where Qd_t stands for the demands for potato, and tomato in each period time; P_t is the prices of potato and tomato in each period time. $popg_t$ stands for growth in population in each period time; PCI_t denotes per capita income of the country in each period. ε_t represents a noise term in each period time.

The Nerlovian model is a dynamic model and the most powerful approach (Braulke, 1982) to measure supply response. Many authors studied agricultural supply response with the help of the Nerlove partial adjustment model (Nerlove, 1979). The approach assumes that a proportion of the difference between current output and long-run desired output is corrected in each period. However, the framework fails to provide sufficient space for dynamic of supply which leads to underestimated elasticity of supply (Nickel, 1995). Hallam and Zanoli (1993) suggest that error-correction models resolve the problem of the traditional Nerlovian model and estimate distinct short-run and long-run elasticities.

The Vector Error Correction Model (VECM) with co-integration analysis is superior to the Nerlovian model as evidenced by Theil (2002), Mackay et al. (1999) and Abdulai & Reider (1995) because it overcomes restrictions on the short-run behavior of variables, and captures the forward-looking behaviour of producers optimising their production in dynamic situations (Nickel, 1995). Furthermore, the response elasticities are also important for policy decision regarding agricultural growth. VECM provides a more functional theoretical framework to examine agricultural supply response. The theoretical framework of the paper is based on an extension of the standard supply function derived from the Cobb-Douglas production function. This study, therefore, employs the VECM to estimate potato and tomato yield and supply responses. There are several reasons for this choice. Most importantly, this approach allows taking into account the fact that the time series data are often non-stationary. Consequently, it overcomes the spurious relationships that are likely to arise when dealing with non-stationary variables at levels. The yield and supply response model used are thus written formally as:

$$Q_t = f(Q_{t-1}, Y_{t-1}, Z_t) \tag{2}$$

$$Y_t = f(Q_{t-1}, Y_{t-1}, Z_t) \tag{3}$$

$$SY_t = f(ST_t, SW_t)$$

$$SQ_t = f(ST_t, SW_t) \tag{4}$$

Where Q_t is the output at time t; Q_{t-1} is the lagged output at time t, Y_{t-1} is the lagged yield at time t and Z_t is a vector of exogenous factors influencing output and yield (i.e., shift factors) at time t, SQt is simulated volume of tomato and potato outputs, SY is simulated tomato and potato yields, STt is simulated technical progress, and SWt is simulated irrigated area. Consequently, it is assumed to follow an autoregressive process of lag one [AR (1)], a static model is not appropriate as it would suffer from serial correlation since the short-run dynamics are captured in the residual. The Johansen cointegration test is a better approach to check the presence of a long-run relationship compared with other approaches (Hallam & Zanoli, 1993; Mackay et al., 1999). If a long-run relationship is established in equation (3), then a single equation error correction model (VECM) for yield and output responses that incorporates feedback from the long-run can be formulated. The VECM is then represented as:

$$\Delta Q_t = \theta_0 + \sum_{i-1}^{n-1} \phi_{1i} \Delta y_{t-i} + \sum_{i-1}^{n-1} \phi_{2i} \Delta Z + \sum_{i-1}^{n-1} \phi_{3i} \Delta Q_{t-1} + \theta_1 (Q - Y - Z) + \phi_{4i} D + V_t \tag{5}$$

$$\Delta Y_t = \theta_0 + \sum_{i-1}^{n-1} \phi_{1i} \Delta y_{t-i} + \sum_{i-1}^{n-1} \phi_{2i} \Delta Z + \sum_{i-1}^{n-1} \phi_{3i} \Delta Q_{t-1} + \theta_1 (Y - Q - Z) + \phi_{4i} D + V_t \tag{6}$$

$$\Delta SQ_t = \theta_0 + \sum_{i-1}^{n-1} \phi_{1i} \Delta ST_t + \sum_{i-1}^{n-1} \phi_{2i} \Delta SW + \theta_1 (SQ - ST - SW) + V_t \tag{7}$$

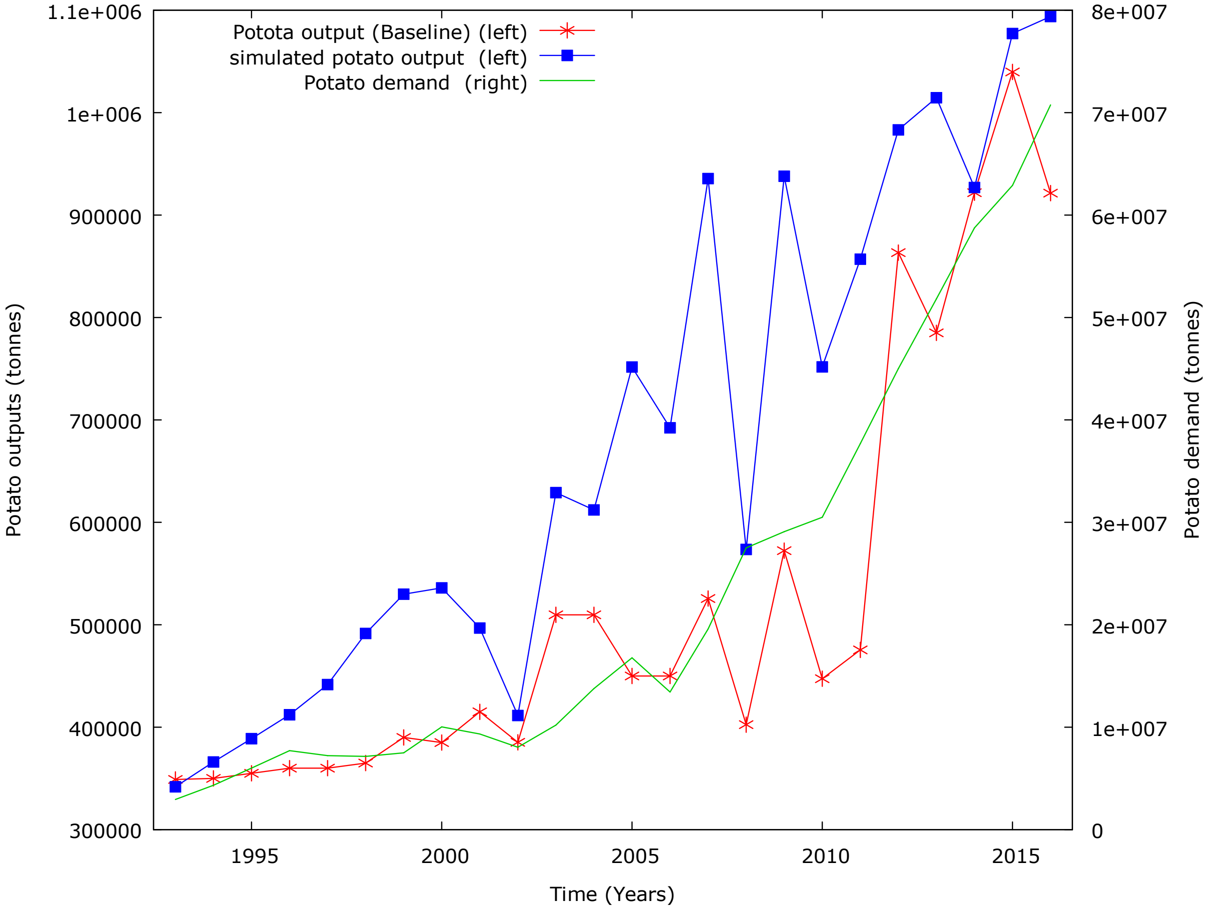
$$\Delta SY_t = \theta_0 + \sum_{i-1}^{n-1} \phi_{1i} \Delta ST + \sum_{i-1}^{n-1} \phi_{2i} \Delta SW + \theta_1 (SY - ST - SW) + V_t \tag{8}$$

The sign Δ denotes the difference operator; D_t is a vector of impulse response dummy that includes industrial policy; V_t is error term. θ_1 is the error correction term which is obtained as residual from the long-run relationship in equation. Thus, the difference between the actual levels of output and its predicted value captures the long-run effect of output. Consequently, equations (5-8) have both long-run and short-run components. The specification in equations (5-8) relates the changes in yield and output in time t to current and lagged values of output and yield and other supply determinants such as price, demand, irrigated area and technical change. The error correction term represents the short-run response required to move output to its long-run equilibrium.

5. Empirical Results

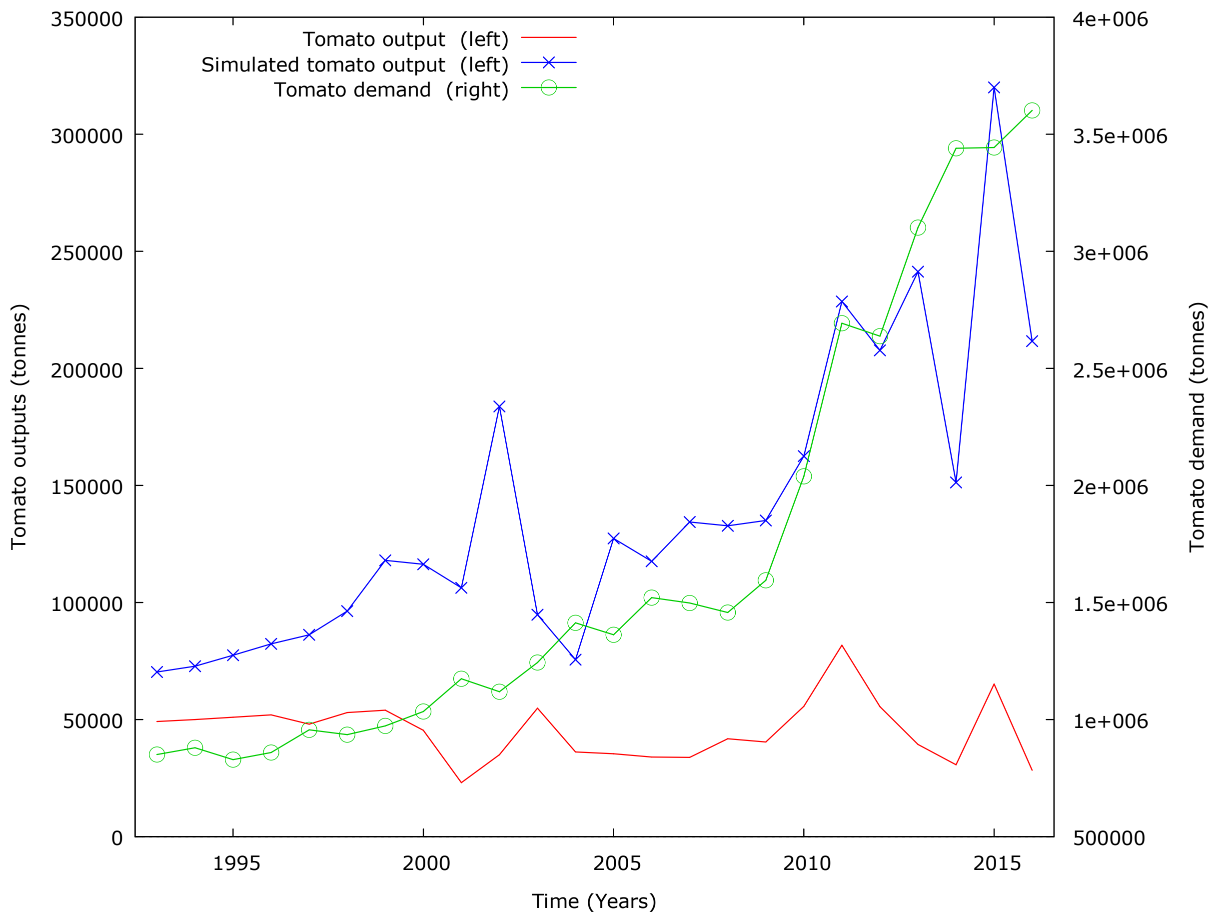
5.1. Trend Analysis of Potato and Tomato Outputs and, Demands

The trend analysis in Figure 1 shows that potato demand has an upward trend because of rapid population growth and industrial policy. Although fluctuation in potato output, producers have generally been increasing the output of potato to meet increasing potato demand due to policy shocks, increasing income per capita and population growth.



Source: FAOSTAT database, 2020.

Figure 1. Baseline and simulated volume of tomato outputs, the volume of potato demand



Source: FAOSTAT database, 2020.

Figure 2- Baseline and simulated volume of tomato outputs, the volume of potato demand

Figure 2 shows that tomato demand has an upward trend from 1993 to 2018, but both large and small fluctuations are observed in its output movement. Evidence has shown that there are substantial fluctuations in tomato output from 1999 to 2013. The figure 3 shows that there is the sharp decline in the price of potato output from 1993 to 2000. The finding shows a noticeable decrease in tomato price between 1993 and 2001 when the price drops from 193 USD per tonne to 112.6 USD per tonne. Since 2002, the tomato price has displayed an upward trend, with a peak of 302 USD per tonne being achieved in 2008. Both potato and tomato prices are volatile since 1993, partly due to poorly organized marketing system. In general, farmers earn better profit when price rises but experience shocks and losses when price falls. Consequently, these situations create instability in price and dis-incentives for producers which discourage them to produce more output. This could have negative implications for the agricultural industry.

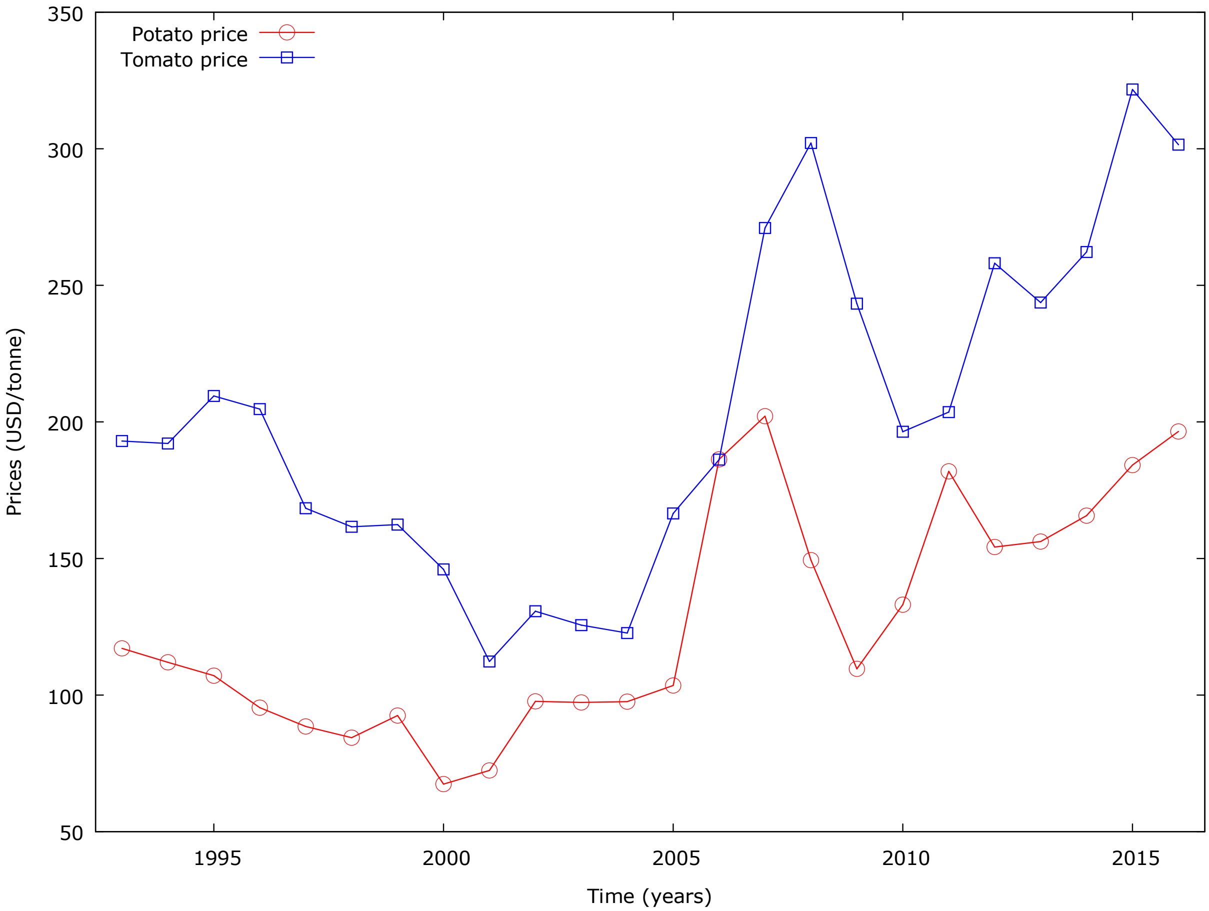


Fig 3-Ethiopian potato price, tomato price from 1993-2018 (USD/ton)

5.2. Results of Unit Root Tests and Johansen Co-integration Tests

Before estimating the model, the unit root tests are carried out for the variables with the help of the augmented Dickey-Fuller (ADF) test. The result indicates that all variables are nonstationary at their levels and stationary at their first differences (Table 2).

Table 2- ADF unit root test with constant results for the following variables

Variable	Level		First differences		
	Test statistic	P-value	Test statistic	P-value	Lag
Potato output	-1.10	0.72	-9.42	0.00	2
Potato yield	-1.42	0.83	-9.83	0.00	2
Potato demand	-0.32	-0.96	-1.61	0.63	3
Potato price	-2.47	0.34	-5.49	0.00	2
Tomato output	-0.71	0.43	-4.20	0.00	3
Tomato yield	-1.22	0.20	-3.51	0.00	3
Tomato demand	-2.21	0.23	-4.54	0.00	2
Tomato price	-0.88	0.89	-2.45	0.17	2
Simulated potato output	-1.54	0.65	-2.20	0.21	3
Simulated potato yield	-0.98	0.96	-3.49	0.04	2
Simulated tomato output	-0.08	0.98	-1.54	0.51	2
Simulated tomato yield	-0.53	0.88	-12.22	0.00	2
Technical progress	-0.57	0.92	-11.91	0.00	2
Irrigated area of potato	-0.65	0.99	-4.72	0.00	3
Irrigated area of tomato	-0.38	0.97	-4.32	0.00	3

Source: Author's estimations from the FAOSTAT database, 2020.
Notes: A lag length is chosen on basis of the Akiake Information Criteria and F-test assuming a maximum lag of three. In the levels and first differences, regressions include constant and trend.

As the result, cointegration tests are undertaken to examine the existence of long-run relationships among all variables with unit roots. The Johansen co-integration analysis is undertaken on the unrestricted VAR using a maximum likelihood estimator (Johansen, 1988). Table 3 shows that there are long-run equilibrium relationships among vectors in the full sample period (1993 to 2018).

Table 3- Results of Johansen Cointegration Test for variables

Variables in VARS	Rank	Eigen value	LMax test	P-value	Trace test	P-value
Potato output	0	0.43	38.58	0.00	80.15	0.00
Potato yield	1	0.31	28.03	0.00	41.57	0.00
Demand	2	0.14	10.07	0.03	13.54	0.02
Price	3	0.03	3.47	0.05	3.47	0.04
Tomato output	0	0.35	49.15	0.00	92.07	0.00
Tomato yield	1	0.23	28.78	0.00	42.92	0.00
Demand	2	0.12	10.77	0.01	14.14	0.02
Price	3	0.01	3.37	0.05	3.37	0.04
Simulated potato output	0	0.55	179.23	0.00	387.65	0.00
Simulated potato yield	1	0.46	82.80	0.00	208.42	0.00
Simulated tomato output	2	0.39	53.05	0.00	125.62	0.00
Simulated tomato yield	3	0.24	28.66	0.00	72.57	0.00
Technical progress	4	0.09	24.63	0.00	43.91	0.00
Irrigated area of potato	5	0.05	19.20	0.01	19.28	0.02
Irrigated area of tomato	6	0.02	0.07	0.03	0.08	0.04

Source: Author's estimations from the FAOSTAT database.
Notes: Rank denotes the number of the cointegrating vector. The Akaike information criterion (AIC) is used to choose the lag-length.

5.3. Results of the error correction model

The estimates of the co-integrating model show only the long-run equilibrium relationships and do not provide any information on the short-run dynamics. The VECM resolves the problem of spurious regression without losing long-run information contained in the level variables. Thus, this study uses the VECM to measure the speed of adjustment towards long-run equilibrium. The higher (lower) speed of adjustment, the lower (higher) would be the dispersion from long-run equilibrium and implied higher (lower) would be the yield and output responses. The result indicates that the speed of adjustment towards equilibrium is quite slow, the numerical magnitude of ECMQp coefficient is -0.02 indicating about 2% of long-run disequilibrium is corrected for in a given year (Table 4). The implied departure from equilibrium is about 98%, and it points towards the lowest potato output response. In the short-run, potato output is unresponsive to lagged yield and demand, but responsive to industrial policy and potato producer price incentive. The coefficient of lagged potato output is -0.56. A 10% increase in the lagged potato output leads to a reduction of potato output by 5.6%, on the other hand, a 10% increase in potato demand leads to an increase in potato output by 1.6% (see Table 4). The negative effect of past potato output level may be due to lack of organized marketing system which results in a low producers' price during peak harvest season and vice versa.

Table 4 shows that potato yield significantly responds to the industrial policy because industrial policy attracts both domestic and foreign investors to invest their capital in this sector.

Table 4- Error correction model for potato output and yield, 1993-2018

Variables	Potato output		Potato yield	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-2.37	-3.63***	-14.23**	-2.31
Lagged potato output	-0.56	1.56	1.34	1.81
Lagged potato yield	-0.01	1.27	0.33	1.56
Potato demand	0.16	0.84	0.17	1.27
Potato producer price incentive	-0.02	3.23***	0.29	0.84
Industrial policy	0.17	2.40**	1.07***	3.23
ECMQp	-0.02	-2.63**	-0.88***	4.40

Source: Author's estimations from the FAOSTAT database.
Notes: All variables (except for industrial policy) are expressed in logarithmic terms. The dependent variables are the logarithm of the potato output and yield. The last row reports adjustment coefficient (error correction term (ECM) coefficient) from an error correction model. A lag length is chosen as using the Akiake Information Criteria and F-test assuming a maximum lag of 3.

There is a significant short-run dynamic relationship between simulated potato yield and technical progress. The ECM coefficient of potato output is -0.65 suggesting about 65% of the deviation from long-run equilibrium is corrected for in one year. The VECM result for the potato yield coefficients is -1.00, is statistically significant at the 1% level of significance. The potato yield adjustment coefficient indicates that about 100% of long-run disequilibrium is corrected for in one year (Table 5).

Table 5- Error correction model for simulated potato output and yield, 1993-2018

Variables	Simulated potato output		Simulated potato yield	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-2.39	-1.18	1.21	-1.18
Irrigated area	1.16	2.73**	1.56	2.43**
Technical progress	2.82	2.96**	16.00	6.98***
ECMSQt	-0.65	-4.62***	-1.00	-7.68***

Source: Author's estimations from FAOSTAT database.
Notes: The last row reports adjustment coefficient (error correction term coefficient) from an error correction model.

Tomato supply response is closely associated with the changes in technical progress and irrigated area. As expected, simulated potato yield positively and significantly responds to change in technical progress in the short-run. The significant short-run response does necessarily suggest that government should work to promote technical changes and irrigation practices. Tomato output is responsive to own lagged output, lagged tomato yield, tomato demand, tomato producer price incentive and industrial policy in the short-run. The magnitude of price coefficient is 0.75, which implies that a 10% increase in tomato price leads to the 7.5% increase in tomato output in the short-run. The coefficient of the error correction term shows the speed of tomato output convergence to the long-run equilibrium as a result of the shock of demand, own price and industrial policy. The negative ECM coefficient (-1.77) indicates that tomato output equilibrium is stable with fast speed of adjustment (Table 5).

Table 6. Error correction model for tomato output, 1993-2018

	Tomato output		Tomato yield	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-13.46	-7.29***	-8.58**	-2.31
Lagged tomato output	0.46	2.42**	0.69	1.81
Lagged tomato yield	-0.82	-4.81***	-0.67	-1.97
Tomato demand	0.86	8.43***	0.54**	2.63
Tomato producer price incentive	0.75	4.17***	0.36	1.00
Industrial policy	0.98	6.40***	0.72**	2.32
ECMQt	-1.77	-7.51***	-0.78	-1.64

Source: Author's estimations from the FAOSTAT database.
Notes: All variables (except for industrial policy) are expressed in logarithmic terms. The dependent variables are the logarithm of the potato output and yield. The last row reports adjustment coefficient (error correction term coefficient) from an error correction model.

The coefficient of the error correction mechanism for tomato yield is 0.78. This means that 78% of disequilibrium in tomato yield is corrected for in a given year. Change in tomato demand over time is found to be a major determinant of short-run tomato yield (see Table 6). Industrial policy shock has the significant effects on the tomato productivity and production.

Table 7- Error correction model for simulated tomato output and yield, 1993-2018

Variables	Tomato output		Tomato yield	
	Coefficient	t-ratio	Coefficient	t-ratio
Constant	-4.85	-2.01	0.07	0.23
Irrigated area	0.95	2.39**	1.66	3.03**
Technical progress	1.49	2.23**	3.50	5.42***
ECMSQt	-0.74	-4.86***	-0.98	4.67***

Source: Author's estimations from the FAOSTAT database.

Tomato output and yield are significantly responsiveness to irrigated area and technical progress in the short-run at the 1% level of significance (see Table 7). The ECM coefficient of 0.98 suggests that about 98% of the deviation from long-run equilibrium is corrected for in any one year.

6. Conclusions

The VECM is used to estimate short-run responsiveness of potato and tomato yield and output to demand, technical progress, irrigated area and price incentives. The key finding is that tomato producers are rational and hence respond to change in demand for tomato. The numerical magnitude of the slope parameter on potato output is relatively lower estimator compared with slope parameter on tomato output. The estimates of the model with the industrial policy reinforce the dominant support for potato and tomato output responses in the short run. The inclusion of this structural break in the model increases the numerical magnitude of the slope parameter on variables and suggests the high supply response to the industrial policy. The results showing the high slope parameter on variables with the observed high supply response and reflect the promotion of technical progress and irrigated area. The numerically high magnitude of the slope parameter on technical progress and irrigated area implies the existence of high supply response which is consistent with the theoretical predictions of the model. Technical progress reduces land scarcity and land values, and can, therefore, increase productivity.

Price policies are needed to reduce the high potato and tomato output variations causing potato and tomato output prices to fluctuate substantially from one production cycle to the next.
The results of the study advise the government of Ethiopia to focus on creating backward and forward linkages among upstream and downstream actors that expand the demand of agro-processing industries for potato and tomato through industrial policy and encourage experience sharing between large scale commercial farmers (i.e., investors) and smallholder farmers. It also increases rural households' incentives and demand for modern inputs which, in turn, lead to higher potato and tomato productivity. The possibility of creating small-scale irrigation systems with support of government could be explored to reduce the heavy reliance on rainfall. The study suggests government to focus on productivity enhancement in the long term, through public investment in irrigation and irrigation materials. The implementation of scenarios will increase potato and tomato productivity which can reduce poverty, including real income changes, employment generation, rural nonfarm multiplier effects and food price effects (Benin, 2016). Increased productivity can also reduce food prices, which increases the purchasing power and real income of urban and rural poor consumers (McIntosha *et al*., 2013).

Competing Interests

There are no conflicts of interest to declare.

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