Volume 70 12 Number 3, 2022

WHAT DRIVES THE AGRICULTURAL GROWTH IN AZERBAIJAN? INSIGHTS FROM AUTOMETRICS WITH SUPER SATURATION

Fakhri J. Hasanov[1, 2, 3], Elchin Suleymanov[4, 5], Heyran Aliyeva[1], Hezi Eynalov[6], Sa'd Shannak[7, 8]

[1] Energy and Macroeconomics Department, King Abdullah Petroleum Studies and Research Center, P.O. Box 88550, Riyadh 11672, Saudi Arabia

[2] Research Program on Forecasting, Economics Department, The George Washington University, 2115 G Street, NW, Washington, DC 20052, USA

[3] Modeling Socio-economic Processes, Institute of Control Systems, 9 Bakhtiyar Vahabzadeh, Baku 1141, Azerbaijan

[4] Department of Finance, Baku Engineering University, Hasan Aliyev 120, AZ0101, Khirdalan, Azerbaijan

[5] The Institute of Economics, Azerbaijan National Academy of Sciences, H. Javid pr., 115, AZ1001, Baku, Azerbaijan

[6] Department of Economics, Baku Engineering University, Hasan Aliyev 120, AZ0101, Khirdalan, Azerbaijan

[7] Qatar Environment and Energy Research Institute, Researchery (HBKU Research Complex), Education City, P.O. Box 34110, Doha, Qatar

[8] Texas A&M University, Water Management and Hydrological Science, College Station – Texas, USA. 77840

Link to this article: https://doi.org/10.11118/actaun.2022.012
Received: 9. 12. 2021, Accepted: 5. 5. 2022

Abstract

The development of the agricultural sector is essential for any economy, including Azerbaijan, the largest economy in the South Caucasus, as it plays an important role in food security, rural development, and environmental protection. For Azerbaijan, as an oil-dependent economy, it is also important for diversification of the non-oil sector. For this reason, the Azerbaijani government has adopted several programs and materialized massive investments to promote agricultural growth. This study examines the role of the production factors in the development of the sector using annual time series data for the period 1995–2017. Econometric analysis, mainly Autometrics - a cutting edge machine learning modeling algorithm- with super saturation, and Growth Accounting lead us to conclude that: (i) land, labor, and capital have statistically significant positive long-run impacts on agriculture output; (ii) the growth of the sector and the contributions of land and capital formation slowed down sharply, while the contributions of total factor productivity (TFP) and labor increased in 2009–2017 compared to the pre-2009 period; (iii) in the pre-2009 period, the sector's growth was hugely contributed by capital followed by TFP, labor and land; (iv) in 2009–2017 period, TFP followed by capital and labor contributed to the sector's growth, while the contribution of land was negative. The results are robust to different econometric methods and specifications. Overall, policymakers are recommended to consider that value-added and other key indicators of agriculture have grown less in 2009–2017 period compared to the pre-2009 period, given that one should expect more growth in the former period as numerous government programs and massive investments were materialized. They may also consider that the contributions of labor and land were quite small and negative, respectively. Lastly, policies leading to TFP growth should be supported.

Keywords: Azerbaijan, agriculture, production function, growth accounting, cointegration, autometrics

INTRODUCTION

After the collapse of the Soviet Union in 1990, the planned economy came to an end and the transition to a new market economy was formed in Azerbaijan, the largest economy in the South Caucasus (WORLD BANK, 2018). It required the identification of competitive sectors to ensure sustainable development of the economy. The oil sector and its export revenues were considered primary in the initial development phase. Starting from 2003–2004, oil revenues were used to invest in other sectors of the economy including agriculture.[1]

The development of the agricultural sector is essential in any economy including Azerbaijan regarding its benefits in rural development, food security, and environmental protection (Yavas and Tuncalp, 1983; Baig and Straquadine, 2014). Agricultural development is one of the natural ways to slow down migration from rural sites to urban cities. Therefore, it contributes to rural development and avoids economic, environmental, demographic, and social problems. Rural population share in total population and the annual growth rate of the rural population both declined from 47.8% and 1.8% in 1995 to 44.3% and 0.13% in 2018, respectively in Azerbaijan (WORLD BANK, 2018). The surveys conducted by CRRC (2007) and Aliyev (2008) show that the willingness of the migrants to return to rural sites is very low. This causes four-dimensional issues, that is, economic, environmental, demographic, and social. Economic issue is that people leave the agricultural labor force participation, which leads to the loss of labor in agriculture and rising unemployment level in the urban areas (see e.g., Aliyev, 2008). As discussed in Appendix A of the online supplementary the share of agriculture in total employment declines as rural people mostly prefer to move to urban areas and work in other sectors than agriculture although the share is the largest in the economy. The environmental issue is that migrated people from the rural areas cause more energy consumption directly and indirectly, which leads to more pollution. Demographic problem is that the migration of the rural people to urban areas may cause imbalances in the gender and age structure of the rural sites. According to the survey conducted by Aliyev (2008), mainly males migrate from rural areas to urban areas, and this left the rural areas with older people, children, and females. Finally, the migration of the rural population to urban areas leads to social challenges such as a shortage in providing public services, in particular when it comes to transportation, communication, and communal services, and may increase the level of crime in urban areas (see e.g., Aliyev, 2008).

Agriculture contributes to sustaining food security, which is a vital issue for any economy. Although the share of foodstuff in total imports declined considerably from 41.5% in 1995 to the period lowest of 10.6% in 2006, it jumped up to 16% and remained around this on average over 2007–2018 (SSCRA, 2019). The alarming point here is that the share tended to increase since 2011 and reached a maximum of 19.4 in 2017, which is the highest since 2000. Additionally, the Global Food Security Index 2019 report ranks Azerbaijan as 53rd country out of 113 countries in the world in terms of overall score (THE ECONOMIST INTELLIGENCE UNIT, 2019).

Environmental protection is one of the main issues in any country over the world as it is urged in the internationally recognized platforms such as the Kyoto Protocol, Paris agreement and United Nations Sustainable Development Goals. The role of the agriculture sector includes reducing emissions and offsetting emissions originated from other sectors in addition to preventing migration from rural areas to urban areas leading to more pollution as mentioned above.[2]

Besides the above-discussed points, there are also two country-specific reasons for the development of the agriculture sector in Azerbaijan. First, the country was known as an agrarian country until the end of the nineteenth century, but it became famous for its oil and gas resources since then. Two climatic zones and nine climatic types of the world are available in Azerbaijan - from subtropical climate to tundra climate. This blessing coupled with productive land areas makes it possible to grow wide range of products. It is possible to get a product more than once in a season. The second reason is to avoid possible negative consequences of the oil sector expansion and to foster economic diversification. The oil sector boom can cause, among other issues, movement of resources (e.g., labor and investment) from non-oil tradable sectors to oil and non-tradable sectors. Also, finite supply of oil and natural gas prevents them to be the core of long-term sustainable development. Such problems can be curbed by diversifying the economy through developing non-oil tradable sectors, such as agriculture and manufacturing as advocated by the conducted studies. This would also support the implementation of strategies, such as Export-led Growth or Import Substitution Industrialization (Hasanov, 2013).

Factors of production, i.e., capital, labor, and available technologies are essential in the development of agriculture. Additionally, it is commonly accepted that government support is needed to promote the sector not only in developing economies but also in developed countries. In this regard, the Azerbaijani government has launched various programs. Among them, the State Programs of Socio-Economic Development of the Regions of Azerbaijan (SPSEDRA) are worth mentioning as they are large-scaled and regularly implemented

1 To save space we use the word of ‘agriculture’ in this paper, which means agriculture, forestry, and fishing sector.
2 This is achieved by mainly eliminating carbon in the atmosphere, storing the carbon in soils, and replacing fossil fuels with biofuels (Paustian *et al.*, 2006; Johnson *et al.*, 2007; Smith *et al.*, 2008; Horowitz and Gottlieb, 2010).

each after 5 years, i.e., for 2004–2008, 2009–2013, 2014–2018, 2019–2023.[3] These programs aimed at boosting agricultural employment, production, exports, and competitiveness, among many others. Implemented direct and indirect measures of these programs are expected to positively affect the sector development through its factors (such as capital, labor, land, and total factor productivity).

The data show that the share of the agriculture value-added in GDP continuously declined from 25.3% in 1995 to 5.3% in 2018. Agriculture was the largest sector of the economy in 1995 but it became the fifth largest in 2018 (SSCRA, 2019). Also, other indicators of the sector discussed above did not demonstrate considerable development in the last decade. This is quite unexpected and necessitates an empirical investigation.

Given the above discussed backdrop, this research aims at investigating main drivers of the Azerbaijani agricultural development for the past more than two decades period. To this end, we first estimate the long-run elasticities of the agriculture output with respect to capital, labor and land in the Production Function framework. Then, we conduct Growth Accounting to reveal the contributions of each factor to the sector's growth.

This study has the following merits. First, to our knowledge, this is the first study to examine the role of production factors in agricultural development in Azerbaijan using the state-of-the-art econometric approach - *Autometrics*, a machine learning modeling algorithm with super saturation. New methods can provide wider information and discover additional features of the process at hand that could not be revealed out using the conventional methods. Second, method- and specification-wise, two robustness checks are performed besides small sample bias corrections to obtain robust results and sound policy recommendations. Third, the study provides theoretically coherent and data-driven evidence on the importance of examining the effectiveness of implemented government programs in future research.

Literature Review

Since the aim of this research is to investigate drivers of agricultural growth in Azerbaijan, we focus on the studies that examine the factors of production and perform growth accounting for Azerbaijan's agricultural sector. Since there are not many studies, we conducted a detailed constructive review below to provide greater benefit to readers.

Humbatova and Hajiyev (2020) investigated the impacts of agriculture investments, agriculture loans and agriculture basic funds on various measures of agriculture output using annual data for 1995–2018. They applied the unit root tests of Augmented Dickey−Fuller (ADF), Phillips−Perron (PP) and Kwiatkowski–Phillips–Schmidt–Shin (KPSS) to identify integration order of the variables. Then, tested whether the variables are cointegrated and estimated long-run relationships using the ARDL bounds testing method by Pesaran *et al.* (2001). They found that the variables are either I(1) or I(0), but not I(2), and concluded that they are cointegrated when agriculture output is measured by total output or livestock output both in the monetary unit of million manat. It was estimated that the elasticity of total agriculture output with respect to agriculture investments, agriculture capital and agriculture loans are 0.66, 0.18 and -0.68, respectively. This paper is greatly acknowledged as it is one of the very few studies that conducted integration-cointegration analysis for the Azerbaijani agriculture sector. We believe that the study would be significantly improved and thus, would be more useful for policy making if the following shortcomings would not exist: (i) a missing theoretical foundation makes it unclear that why agriculture output depends upon only investment, funds, and loans ignoring other factors such as land and labor; (ii) one can suspect that all three explanatory variables used can create a multicollinearity issue and thus, inefficient estimates. This is a good reason to suspect that why the impact of loan is negative whereas one should expect a positive impact. The author acknowledge that negative impact of loan was unexpected but no explanation for this was provided; (iii) out understating from Tab. I of that paper is that nominal values of the variables were used in the study, which might lead to misleading conclusions due to the inflationary effect.

Hasanli and Rahimli (2020) estimated capital and labor elasticities of output of agriculture, construction, manufacturing, and mining sector. They considered the Constant Elasticity of Substitution (CES) production function as a theoretical framework and used annual time series data spanning from 2006 to 2017. It was found that capital and labor elasticity of agriculture output are 0.69 and 0.31, respectively. This study has the following merits although it did not address integration and cointegration properties of the data used and less attention was paid to agriculture as it was one out of four sectors: (i) it considered production function framework as a theoretical foundation rather than selecting the explanatory variables in an ad-hoc manner; (ii) used real values of capital and output.

3 The government also adopted the Strategic Road Map for the Production and Processing of Agricultural Products in the Republic of Azerbaijan for 2016–2025 and the State Program on the reliable food supply of population in the Azerbaijan Republic for 2008–2015.

Using annual panel data, Vafa *et al*. (2020) conducted the growth accounting for total output and agriculture output for Azerbaijan, Belarus, Georgia, Moldova, and Ukraine considering the Solow–Swan model with the Cobb-Douglas production function as a theoretical framework. They also did a panel regression analysis with random and fixed effects for total output growth and agriculture output growth. Their growth accounting calculations for the entire period of 1995–2015 showed that 2.2% of the Azerbaijani agriculture growth was mainly driven by agriculture capital growth (7.2%) while the contributions of agriculture labor and agriculture TFP were very small (0.3%) and negative (-5.3%), respectively. However, the authors' 5-year sub-period breakdown calculations for 1995–2000, 2001–2005, 2006–2010, and 2011–2015 revealed that over time, the contribution of capital declined while the contributions of TFP increased significantly. Numerically, the contribution from capital declined from 29.6% in 1995–2000 to -2.8% in 2001–2005, and it grew from 0.9% in 2006–2010 to 1.0% in 2011–2015. The labor contribution increased from -0.3% in 1995–2000 to 1.0% in 2001– 2005 and further increased to 0.3% in 2006–2010, then slightly declined to 0.2% in 2011–2015. As for the TFP contribution, it was terribly negative, -31.5%, in the first sub-period. It increased to 3.2% and 4.0% in the next two sub-periods, respectively, and slightly decreased to 3.2% in the last sub-period. Our main concern about this paper is that integration, cointegration, cross-sectional dependency and heterogeneity features of the panel data have not been addressed. Also, we could not find any discussion about how the labor and capital elasticities have been estimated or calculated and we could not find their numerical values either.

Humbatova and Hajiyev (2017) analyzed the production function of the industry and agriculture sectors of the regions of Azerbaijan using the annual time series data spanning from 2005 to 2015. They did econometric estimations and found some numerical values for the sectors in different regions. We acknowledge that this is one of the pioneer studies that examined the production function relationship for the agriculture sector. The study did not estimate the production function for the total agriculture sector. Additionally, the study has some shortcomings. For example, it estimated and reported negative capital or labor elasticities of output for some regions without any explanations. Additionally, integration and cointegration properties of the time series data used have not been examined and hence, it is not known whether the estimated equations represent long-run relations, or they are just spurious. Moreover, sometimes either labor or capital dropped from the estimations.

Acosta and Luis (2019) estimated TFP growth for crops, ruminants and monogastrics of 114 countries including Azerbaijan over the period 1992–2014 employing a stochastic distance function approach. For Azerbaijan, they found TFP growth to be 1.013, 1.033 and 1.054, respectively. However, the study did not estimate the impacts of the production factors on the mentioned products' output.

Van Berkum (2017) analyzes the competitiveness of the agricultural sector and examines the trends in production and in consumption of agricultural products such as crops, livestock products, the trade position of the agricultural market and factors affecting current and future demand for agricultural and food products between 2000–2016. He finds out that the consumption of potatoes, vegetables and fruits, and protein-rich products like milk, fish and eggs have increased but bread consumption is decreased in the past 15 years. He concludes that as the increasing domestic demand for potatoes, fruit, vegetables meat, fish and eggs are driven by income growth and urbanization trends, these trends will provide opportunities for domestic production. The challenge for the domestic agricultural supply chain is to comply with quality, food safety and environmental standards of modern food retail channels, and with international standards. Also, Aliyev (2018) recommended the priority direction of agricultural development as well as soil and water conservation.

Destek *et al*. (2017) examine the impact of oil rent as a share of GDP on agriculture's share of GDP in Azerbaijan, Kazakhstan, Kyrgyzstan, and Uzbekistan to see if there is evidence of Dutch disease. The ARDL bounds test method is applied to annual time series data from 1991 to 2013. For Azerbaijan, they find that the share of agriculture in GDP is statistically significantly negatively affected by the share of oil rent in GDP in both the short and long run.

Using Bella Balassa's approach, CESD (2015) tried to find out the comparative advantages in the export of agricultural products. To compare countries, the Balassa index is used to examine European countries (Spain, Italy, France, and Germany) and Azerbaijan regarding the production of hazelnuts, tropical fruit juice, and apple juice in 2011, 2012, and 2013. The results show that in comparison with Italy, Azerbaijan has no comparative advantages to produce hazelnuts, but the country has comparative advantages over Germany, Spain, and France with the same product. But there was no advantage in terms of tropical fruit juice and apple juice. From the CIS countries during the period 2011–2013, Azerbaijan has comparative advantages with hazelnuts product over Belarus, Kazakhstan, Ukraine, and Russia.

We conclude our literature review with the following observations: (i) there are quite limited studies investigating drivers of agriculture growth in Azerbaijan; (ii) the existing papers suffer from the miscommunication of econometric methods such as integration and cointegration analysis; (iii) no time series study conducted growth accounting; (iv) the panel study conducting growth accounting did not report country specific factor elasticities of agriculture output. In this study, we will address the above limitations of the existing literature on Azerbaijani agriculture.

Theoretical Framework

Production Function for the Agriculture Sector

The agriculture sector is one of the types of economic activities, where goods are produced. Therefore, it is quite reasonable to consider production function theory as an underpinning of this study. We use Cobb-Douglas Production Function (CDPF, Cobb and Douglas, 1928) for this purpose. The CDPF can be expressed as follows:

$$Y_t = A \times L_t^{\alpha} \times K_t^{\beta}. \quad (1)$$

Where, Y is real output; L and K are the labor and real capital stock, respectively; t denotes time. α and β are elasticities of output with respect to labor and capital and A is the intercept coefficient, which all will be econometrically estimated.

Considering the nature of the agricultural production, (1) can be extended with other factors to provide more information. For example, capital stock can be divided into the capital formation (*CF* capital hereafter) and land area (*LA*). Then, (1) can be written as.

$$Y_t = A \times L_t^{\alpha} \times CF_t^{\delta} \times LA_t^{\varphi}. \quad (2)$$

If the constant return to scale hypothesis holds, then the following is true: $\alpha + \delta + \varphi = 1$.

Per labor version of the CDPF above, where both sides of (2) are divided by labor, is also used in empirical and theoretical studies. It takes the following form:

$$YPL_t = A^* \times CFPL_t^{\delta} \times LAPL_t^{\varphi}. \quad (3)$$

One of the reasons for using (3) instead of (2) is to investigate labor productivity rather than overall output of agriculture. Another reason is that it provides a parsimonious theoretical framework that is relevant for econometric analysis when the sample period is short, since it has one less variable compared to (2).

If we express (3) in the natural logarithm form and add the error term (ε) to make it a regression equation to be estimated econometrically, we will get the following log-linear specification:

$$ypl_t = \alpha^* + \delta cfpl_t + \varphi lapl_t + \varepsilon_t. \quad (4)$$

Where, *ypl*, *cfpl* and *lapl* are natural logarithm expressions of per labor agriculture production, per labor agriculture capital, and per labor agriculture land area, respectively.

Labor elasticity can be calculated once the capital and land elasticities are estimated, that is:

$$\alpha = 1 - \delta - \varphi. \quad (5)$$

A number of agriculture-related studies employed the CDPF framework in their analysis. For example, Felloni *et al.* (2000), Antle (1983), Faridi and Murtaza (2013), Evenson and Mwabu (1998), and Timmer and Block (1994), Hasanov and Shannak (2019), as well as those for the Azerbaijani agriculture that we reviewed in the previous section. Note that the above-given equations can be expanded by including other variables that are believed to be relevant for explaining the agriculture production depending on the data availability.[4]

TFP Calculation and Growth Accounting

TFP can be calculated using either direct or indirect methods (see, e.g., Diewert, 1988, 1992). The indirect methods involve estimating an appropriate production function, from which TFP time series can be calculated as follows:

$$TFP_t = \frac{Y_t}{CB_t^{\delta} \times LA_t^{\varphi} \times L_t^{(1-\delta-\varphi)}}. \quad (6)$$

The left-hand-side of equation (6) is called the "Solow residual".

Using the natural logarithmic expression of the variables the following formula can be obtained:

$$tfp_t = y_t - (\delta cb_t + \varphi la_t + (1 - \delta - \varphi) l_t). \quad (7)$$

Once TFP is calculated, growth accounting identity can be written as follows:

$$\Delta y_t \times 100 =$$
$$= \Delta tfp_t \times 100 + \delta \Delta cb_t \times 100 + \varphi \Delta la_t \times 100 + (1 - \delta - \varphi) \Delta l_t \times 100. \quad (8)$$

Here, Δ is first difference operator. Lower-case letters mean the natural logarithmic expressions of the variables. The growth accounting shows contributions of the growth of each input and TFP to the growth of output.

MATERIALS AND METHODS

Data

This study uses annual time-series data spanning from 1995 to 2017. The period is dictated by the data availability. Following the theoretical framework above, the variables are defined as follows:

4 As Appendix C.4. discusses, additionally, we included fertilizers, pesticides, and precipitation in equation (1) in our robustness check.

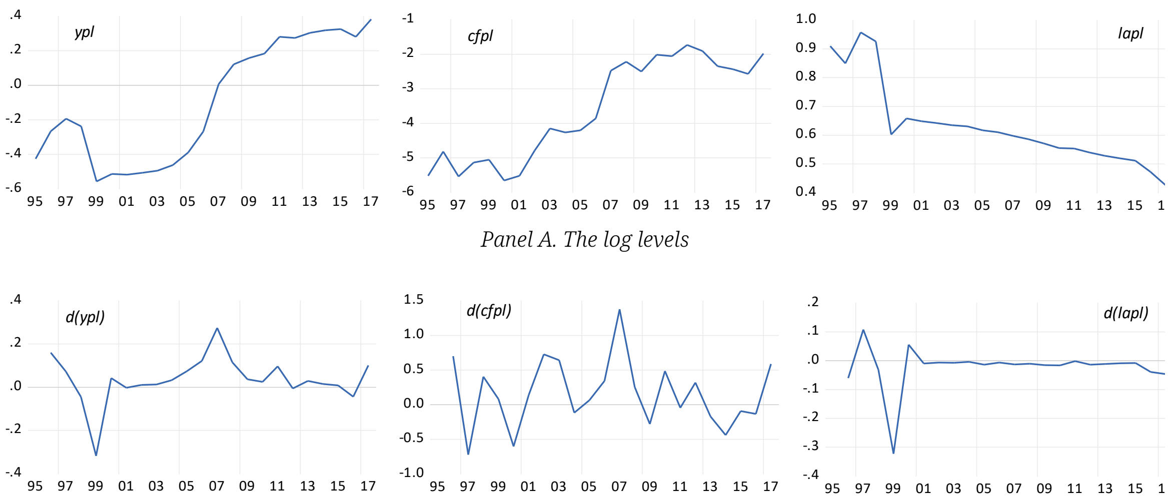
- *Agriculture Production per Labor* (*YPL*). This is the goods produced in the agriculture, forestry and fishing sector in Azerbaijan measured in thousand manats at 1995 prices in per labor term. The variable is calculated as follows. The nominal values of the production at actual prices of million manats deflated by the price index of agricultural, 1995 = 100 (*PAGR*). Then, the resulted real values are divided by the number of employed populations in agriculture, forestry and fishing measured in thousand persons (*L*).
- *Agriculture Capital Formation per Labor* (*CFPL*). This is the gross fixed capital formation (GFCF) in the agriculture, forestry and fishing sector in thousand manats at 1995 prices per labor term. The nominal values of GFCF in million manats are deflated by *PAGR* to get the real values.[5] Using GFCF as a measure of capital stock in econometric estimations is not unusual as theoretical and empirical appropriateness of it has been supported by many studies (see e.g., Ram, 1986; Soytas and Sari, 2006, 2007; Soytas *et al.*, 2007; Apergis and Payne, 2009, 2010; Zhang and Yang, 2013; Shahbaz *et al.*, 2015 for theoretical and empirical applications).
- *Agriculture Land Area per Labor* (*LAPL*). This is the sum of land area for permanent crops and land area for hayfields and pastures measured in thousand hectares divided by the employment in thousand persons to get per labor term.[6] Apparently, we consider both the land area for plant-growing production and that for livestock because (i) the agriculture production comes from the productions of these two activities and (ii) the average share of the former in total agriculture production (in actual prices of million manats) was 50% in 1995–2017 and even more since 2013.

I: *Descriptive statistics of the variables*

	YPL	*CFPL*	*LAPL*
Mean	0.96	0.06	1.90
Median	0.82	0.02	1.83
Maximum	1.47	0.18	2.61
Minimum	0.57	0.003	1.53
Standard deviation	0.33	0.06	0.30

All the needed indicators in the calculations above were taken from the State Statistical Committee of the Republic of Azerbaijan (SSCRA, 2019).

Tab. I records descriptive statistics of the variables and Fig. 1 illustrates natural logarithms and growth rates of them in 1995–2017. Tab. I shows that the mean and median values calculated over 23 observations are quite close for *YPL* and *LAPL* variables. For *YPL, CFPL,* and *LAPL* the maximum values are recorded in 2017, 2012, and 1997, respectively, while the minimum values are observed in 1999, 2000, and 2017, respectively. The last row of the table shows that the highest deviation from the mean value is recorded for *YPL*, followed by *LAPL* and *CFPL*. The most noticeable two observations from Fig. 1 are the similar time trajectories of *ypl* and *cfpl*, and the steady decline in *lapl* after 2000.



Panel A. The log levels

Panel B. The growth rates

1: *Time profile of the variables*

5 Note that before GFCF, we considered capital stock that we calculated using GFCF in real terms, 5% depreciation rate and initial capital-output ration of 1.5 in the Perpetual Inventory Method framework (see Nehru and Dhareshwar, 1993; Collins *et al.*, 1996). However, the unit root tests concluded that the capital stock is an integrated order of two, I(2), variable and therefore, we opted to GFCF, which is an I(1) variable as discussed in Appendix C.1.

6 The reason for taking the land area for permanent crops is that we are interested in the long-run aspects of the agriculture growth in this research.

Econometric Methodology

The empirical strategy of this research is as follows. First, the non-stationarity properties of the variables are tested. If all variables are integrated of the same order, the long-run common movement, i.e., cointegration feature of them is tested. After confirming the cointegrated relationship, the parameters of this relationship for agriculture output are estimated. Otherwise, short-run relationship of agriculture output growth should be estimated using a growth equation of the agriculture output. Two types of robustness checks - method-related and specification-related - are performed to ensure that the results obtained are sound. Lastly, growth accounting is conducted to assess contribution of each factor to the agriculture output growth.

We use the Augmented Dickey-Fuller (ADF hereafter, Dickey and Fuller, 1981) and Phillips-Perron (PP hereafter, Philips and Perron, 1988) unit root tests in testing non-stationarity properties of the variables to get robust inferences about the integration order of the variables.[7] The null hypothesis of both the tests is that a given variable has a unit root.

The theory of cointegration predicts that if more than one explanatory variable is included in the analysis, then there can be more than one long-run relationships among them (see, e.g., Engle and Grange, 1987; Enders, 2015). Hence, we should first employ system-based cointegration test methods as only these methods can discover number of cointegrating relationships if they are more than one. To this end, we employ the reduced rank cointegration method in the Vector Equilibrium Correction (VEC) modeling framework developed by Johansen (1988), Johansen and Juselius (1992). This framework also provides a comprehensive environment to test weak exogeneity assumption for the explanatory variables involved in the analysis. Weak exogeneity of the explanatory variables is an important assumption for the application of the single equation methods, such as ADL (Autoregressive Distributed Lagged) that we use in this study (see e.g., Ericsson and MacKinnon, 2002).

It is known that the VEC model works better with longer sample sizes. Since we have small number of observations, we consider the ADL as a primary estimation method as it produces more consistent estimates compared to other alternative methods in small samples (see e.g., Banerjee *et al.*, 1998; Pesaran and Shin, 1999; Pesaran *et al.*, 2001; Enders, 2015). We apply the ADL in the general to specific modeling (*Gets*) framework using *Autometrics* - a machine learning modeling algorithm (see, e.g., Ericsson, 2021). *Gets* with *Autometrics* has many advantages over other modeling frameworks as it is documented in the literature.[8] Additionally, we use *Autometrics* with super saturation in PcGive toolbox in OxMetrics 8.0 (Doornik, 2009, chap. 4; Doornik and Hendry, 2009, 2018). Key advantage of the super saturation is that it can capture a one-time jump or drop, a jump followed by a drop or vice versa, and a shift in the level of the variable under consideration. For the application of the *Gets* using *Autometrics* with super saturation, we follow Hendry (2020) and Castle *et al.* (2021) as they provide a comprehensive guidance.

For the method-related robustness, we used two more methods to test cointegration and estimate level relationship, in addition to VECM and ADL above, and accounted for small sample bias correction in the cointegration tests. They are presented in Appendix C.2.

DISCUSSION

Discussion of the Econometric Results

The unit root test results conclude that the variables, i.e., production, land and capital all in per labor terms are non-stationary at their log levels but their growth rates are stationary (see table and discussion in Appendix C.1.). According to the results of the cointegration tests, there is a common stochastic trend among the variables (see tables and discussions in Appendix C.2.). In other words, per capita agriculture output moves together with per capita capital and land meaning that the relationship that it establishes with the latter variables is expected to be in line with the theory of production.

Tab. C.III in Appendix C reports the long-run estimation results for equation (4) from the ADL model using *Autometrics* with super saturation in the *Gets* framework. We obtained the long-run elasticities of agriculture production with respect to land and capital are in the range of [0.40; 1.32] and [0.05; 0.21], respectively considering the estimated coefficients and their two times standard errors. Apparently, both the ranges are statistically significant as they do not cross the zero line. We calculated labor elasticity to be 0.39 (1-0.40-0.21) according to equation (5) and considering the lower bound value of land elasticity and upper bound value of capital elasticity.

If the land area expands (decreases) by 1% then the agriculture output increases (declines) by 0.4%, in the long run, keeping other factors constant.

7 Additionally, we may apply unit root test with structural breaks such as Fourier ADF developed by Enders and Lee (2012a, b) or Fourier ADF with structural breaks developed by Furuoka (2017) if the unit root test results from the ADF and PP tests are not consistent with each other or if the results are in contrast with conventionally preferred integration order of a given variable (e.g., usually output and labor should not be expected to be I(2) variables).

8 See Epprecht *et al.* (2021), Desboulets (2018), and Castle *et al.* (2011) among other studies.

Theoretically, it is impossible to imagine agriculture activity without land as both types of agriculture activities, i.e., crop production and livestock farming are closely linked to the land areas unlike economic activities in other sectors. This theoretical articulation holds true for Azerbaijani agriculture with the largest elasticity compared to those of capital and labor. The country has nine out of 11 climate zones, which make land areas most favorable for agricultural activity. However, land area per labor has declined persistently since 2001 as illustrated in Panel A of Fig. 1. The drop accelerated after 2007 and became severe after 2015. Statistically, the land areas for permanent crops, hayfields, and pastures areas declined from 2915 thousand hectares in 2000 to 2683 thousand hectares in 2017, an 8% decline (SSCRA, 2019). This would contribute to a 3.2% decrease in agriculture production over the same period. Further investigation revealed that the main source of this decline was the drop in the land area for hayfields and pastures since 2006 (see Fig. A.2A in Appendix A). Such circumstance necessitates the implementation of the appropriate legislative, direct and indirect measures by the authorities to prevent the decline. Therefore, this issue is on the government's agenda as it is highlighted in the Strategic Roadmap for the Production and Processing of Agricultural Products in the Republic of Azerbaijan adopted in 2016 (ARASRM, 2016). The lack of studies on the Azerbaijani agriculture does not allow us to compare our estimated land elasticity with others.

Empirical analysis shows that a 1% increase (decrease) in capital leads to a 0.2% raise (reduction) in the Azerbaijani agriculture production in the long run. Theoretically, both Keynesian and Neoclassical schools of thought predict that investment and thus capital stock is one of the key drivers of economic growth. Empirically, one should expect a positive impact of capital on the output in the agriculture activity in Azerbaijan as the government has put a lot of investments in the developments of the agriculture sector through the established government agencies, such as the Azerbaijan State Investment Company (ASIC), the National Fund for Entrepreneurship Support (NFES), and the Azerbaijan Export & Investment Promotion Foundation (AZPROMO) in line with the adopted different governmental programs and strategies, such as SPSEDRAs adopted for 2004–2008, 2009–2013, 2014–2018, Strategic Roadmap on production and processing of agricultural products in the Republic of Azerbaijan adopted in 2016. Regarding previous studies, Humbatova and Hajiyev (2020) and Hasanli and Rahimli (2020) estimated the capital elasticity of agricultural output to be 0.2 and 0.7 for the periods 1995–2018 and 2006–2017, respectively. Our estimate is more comparable to that of Humbatova and Hajiyev (2020) because the sample period they used is almost identical to ours. Nevertheless, we should be cautious about the level of robustness of the estimates in both studies for the reasons stated in the literature review section.

Generally, capital formation in the agriculture sector follows the pattern of government expenditures, which are tightly linked to the international oil prices given that Azerbaijan is an oil-exporting economy. Also, the trajectories of agriculture production were quite similar to those of its capital over the period investigated (see Fig. 1, Panel A). The chain of the economic reasoning is that high oil prices at the international markets allowed the government to spend more in financing investment projects including those in the agriculture sector, which resulted in higher economic activity and production in the sector.[9]

According to the empirical analysis, a 1% increase (decrease) in the employed population in the agriculture sector leads to a 0.4% increase (decrease) in production in the long run. The theory of the production vividly articulates that labor is one of the main drivers of output (Cobb and Douglas, 1928). This theoretical expectation holds true in the case of the Azerbaijani agriculture. The share of agriculture in total employment was higher than 36% whereas the sector's share in total GDP was only around 6% since 2008 (Fig. A.1A and A.1B). It is also theoretically predicted that the labor elasticity of the output should be usually greater than that of capital (e.g., see Senhadji, 2000; Cherif and Arezki, 2010 inter alia). In this regard, our labor elasticity is larger than the capital elasticity. As for the findings of previous studies, only Hasanli and Rahimli (2020) estimated the labor elasticity of agricultural production, which was 0.3 for the period 2006–2017.

Panel B of Tab. C.IV documents that the speed of adjustment (SoA) coefficient is -0.63 meaning that 63% of the deviations of the agricultural production from its long-run equilibrium level caused by shocks will be adjusted in next year. This is a quite fast adjustment and should encourage the policymakers to implement progressive measures for the sector's development. Among the previous studies, we know only Humbatova and Hajiyev (2020) estimated SoA coefficient for agricultural output, but they reported that it was not statistically significant.

9 The same logic applies when the international oil price is low. For example, the sharp drop in international oil prices in 2016 was most likely the main reason for the decline in government revenues and spending and, consequently, investment and production in agriculture.

The estimation results indicate that the break in the development trend of the agricultural sector in 2007 was statistically significant and added 3% to the average annual growth rate of the sector, holding other factors constant. Most likely the break has been caused by the surge in the spending of oil revenues for the development of different sectors including agriculture during the oil boom period as explained above.

Finally, we performed two types of robustness checks, method-based and specification-based, to make sure that the estimation and test results obtained above are robust. Appendix C.3 documents the results of the method-related robustness, while the results of the specification-related robustness are presented in Appendix C.4. According to the results, the obtained estimation and test results are robust to different econometric methods and extended specifications of agricultural productivity.

Discussion of the TFP Calculation and Growth Accounting

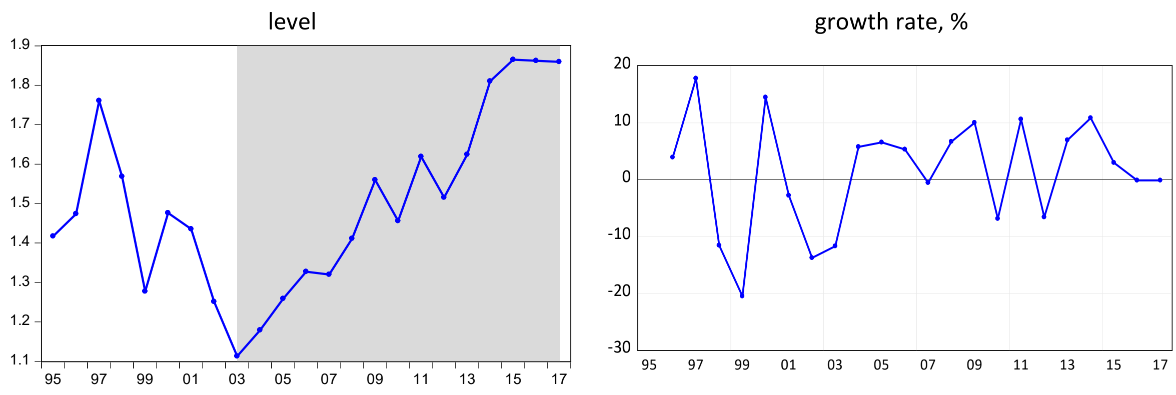
We calculated TFP based on equation (7) and using the ADL-based estimated elasticities of 0.40, 0.21, and 0.39 for land, capital, and labor, respectively. Fig. 2 illustrates the level and growth rate of it.

The TFP has a downward trajectory in 1995–2003 and an upward trajectory in 2004–2015 followed by flattening level for the last two years. Till 2003, TFP growth rates were largely volatile. It saw growth in 2004–2009 (except for -0.6% in 2007) and 2013–2015 and volatility in between before ending with -0.1% for each year of 2016 and 2017. This might imply that TFP is mainly driven by oil sector developments. A similar picture was found for other oil-exporters (e.g., Hasanov *et al.*, 2019 found that TFP in Saudi Arabia follows the oil sector development patterns). We will discuss the impact of TFP on the agriculture output later in this section.

Finally, we conducted the growth accounting using equation (8) to demonstrate the contributions of capital, land, labor, and TFP growth to the output growth in the agriculture sector. We calculated 5-year average values of the growth accounting for 1996–2017 period, which are matched with the durations of the SPSEDRAs, i.e., 2004–2008, 2009–2013, and 2014–2017. Fig. 3 illustrates the average values.[10] The figure provides some noteworthy observations regarding the role of the factors in the development of the agriculture sector. Overall, both the agriculture output growth and contributions of its factors slowed down throughout the time horizon of the SPSEDRAs.

Precisely, agriculture output growth and contributions of the drivers were the highest in 2004–2008 (the period of the first SPSEDRA) compared to 2009–2013 (the period of the second SPSEDRA) and 2014–2017 (the period of the third SPSEDRA).

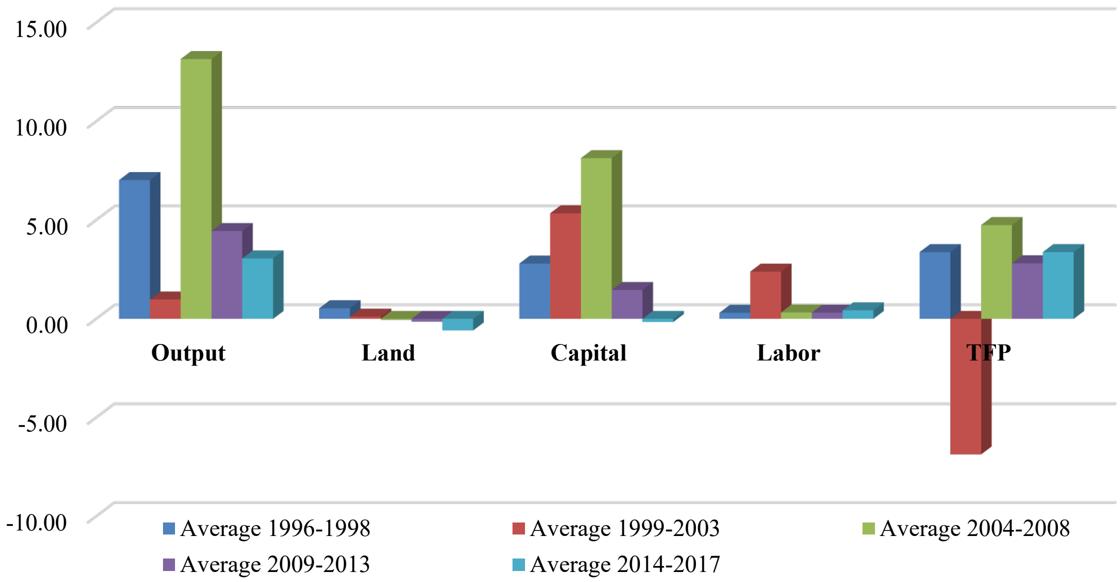
Fig. 3 illustrates that the contribution of land to the agriculture output growth was very small, diminished and even turned to expanded negative over time. Such poor performance probably stemmed from the fact that the land area declined significantly since 2007 (see Fig. A.2A), although its estimated elasticity was the largest from all various estimations (see Tab. C.II–C.V). We have three possible explanations for this finding. First, a significant migration of the rural population to urban areas due to the expansion of non-tradable sectors such as construction and services as a result of the oil boom since 2006–2007 in Azerbaijan may have led to the agricultural land being unused/unmanaged. Second, it may be that the development of other sectors, particularly services, including tourism,



level *growth rate, %*

2: *TFP in the agriculture sector, 1995–2017*

10 We aligned the values with the time spans of the SPSEDRAs because only these programs are adopted in each after five years since 2004. The growth accounting for each year of the entire period of 1996–2017 can be obtained from the authors under request.



3: *Growth accounting in agriculture matched with SPSEDRAs' periods, %*

caused agricultural land to be occupied and used for purposes other than agriculture. Third, it could also be that wealthy individuals and companies have purchased land areas for investment purposes and left them unused.

Capital can be considered as one of the main contributors of agriculture output growth for the entire period. Its contribution, however, declined after 2004–2008 and even became slightly negative. Precisely, its average contribution grew from 2.8% in 1996–1998, to 5.3% in 1999–2003, and 8.1% in 2004–2008 and then it declined to 1.5% in 2009–2013 and -0.2% in 2014–2017. The diminishing contributions in 2009–2017 were mainly caused by considerably low capital growth: the average growth rate was 31.8% in 2000–2008 and 3.6% in 2009–2017.[11]

The labor contribution increased from 0.3% in 1996–1998 to 2.4% in 1999–2003 and declined to 0.3% again for 2004–2008 and 2009–2013 and was 0.4% in 2014–2017. Only a 0.1%-point increase is recorded if the recent three 5-year averages is considered. Apparently, the contribution of labor to agriculture output is quite small compared to that of capital although its elasticity was the second largest. This implies that growth rate of labor was not so large during the period under consideration. Indeed, the average growth rate for labor was only 2.1%, while for capital it was 18.2%, about nine times higher over the period 1996–2017.

Fig. 3 shows that TFP was the largest contributor of the agricultural output growth when the 2009–2013 and 2014–2017 periods were considered. Comparing the average value of the 2009–2017 period with that of the 2000–2008 period, to have the same number of years in each period, the contribution raised from 1.1% to 3.1%, a threefold increase. One should be careful when interpreting the TFP and its contribution. Therefore, we discussed rivaling views on TFP as a measure of productivity and further examined its elements in Azerbaijan in Appendix D. We concluded from the discussion in the appendix that most likely the TFP we calculated mainly contains signals representing developments in various indicators such as new ideas, institutions, technological improvements, economies of scale, integration among firms, better organization, and management rather than noises.

Particularly, we are concerned by the finding that the agriculture output growth slowed down considerably after 2008 although the state programs were implemented, and investments materialized for the development of the sector. We critically approached our measure of the agriculture output thinking that perhaps it does not represent well the sector's developments. To this end, we considered other measures - agriculture outputs quantified in volume terms such as tons and numbers/heads as they are not subject to the conversion issues from nominal values to real values. Tab. II documents

11 The growth rate was calculated as the first difference of log value time by 100 to be consistent with the data transformation used in the estimations. Note that we calculated the real values of the agriculture gross fixed capital formation by deflating nominal values by agriculture production index as the Data section describes. One can use another deflator measure and end up with different real values. Even if the nominal values of gross fixed capital formation considered, the average growth rates are 69.0% for 2000–2008 and 13.5% for 2009–2017.

II: *Average growth rates of agriculture outputs, %*

Indicator	2009–2017	2000–2008
Total crop production, all categories of farms, thousand tons	2.1	9.4
Total number of animals and poultry, 1 January, all categories of farms, 1000 heads	2.6	4.4
Total meat production, in slaughtered weight, all categories of farms, 1000 tons	3.7	5.0
Total milk production, all categories of farms, 1000 tons	4.4	3.7

Notes:
Total crop production is the sum of cereals and dried pulses, cotton, tobacco, potatoes, vegetables, watermelons and melons, sugar beets, and sunflower for seed.
Total number of animals and poultry is the sum of beef cattle, sheep and goats, pigs, poultry, horses, donkeys, camels, and mules.
Total meat production is the sum of beef meat, mutton and goat meat, pork meat and poultry meat.
Total milk production is the sum of cow and buffalo milk, sheep and goat milk.
The data are from SSCRA (2019, https://www.stat.gov.az/source/agriculture/?lang=en).

the average growth rates of these measures for two sub-periods, i.e., 2009–2017 and 2000–2008.

Again, all the main indicators of agriculture output in the table except milk production saw more growth in 2000–2008 than in 2009–2017 on average. This supports what Fig. 3 illustrate: the agriculture output growth slowed down during 2009–2017.

Thus, the results of the long-run analysis and the growth accounting can be summarized as follows: (i) the agriculture output establishes a long-run relationship with the land, labor, and capital – the latter ones have statistically significant positive impacts on the former one; (ii) capital followed by TFP and labor were the main contributors of the agriculture output growth while the land contribution was slightly negative during the whole period of 1996–2017; (iii) the agriculture output growth and the contributions of land and capital formation slowed down sharply, while the contributions of TFP and labor increased slightly in 2009–2017 compared to the pre-2009 period; (iv) in pre-2009 period, sector's growth was mainly contributed by capital followed by TFP, labor and land; (v) in 2009–2017 period, TFP followed by capital and labor contributed to the sector's growth, while the contribution of land was negative.

The above findings are not in line with the objectives of SPSEDRAs and other government programs as they aim to increase socio-economic development of regions where agriculture is a key element (see, e.g., SPSEDRA, 2014; AERR, 2017). This could mean that measures implemented under government programs, including SPSEDRAs, up to 2008 had a greater positive effect on agricultural development than those implemented thereafter. However, we cannot assert this because data unavailability did not allow us to assess the explicit impact of the government programs on agricultural development in this study.

Apparently, sometimes estimating coefficients are necessary but not sufficient to reveal out the entire picture of the process at hand. In this regard, our econometric estimates showed that the land elasticity of agricultural output is the largest, but the growth accounting showed that land makes a small positive and then even negative contribution to the growth of the sector.

CONCLUSION

Agriculture is an important sector because it helps to attain food security, keeping the balance between rural and urban population and development, foster economic diversification. Additionally, it has a large share in total employment and climate condition is very favorable for the sector's development in Azerbaijan. The Azerbaijani government has adopted a number of state programs and materialized a considerable financial resource to boost developments of the regions and sectors including agriculture. These conventional and country-specific issues, and the fact that very little research exists, led us to conduct this study.

We investigated what role the theoretically formulated determinants of agricultural production played in its development over the period 1995–2017 by performing econometric estimations and growth accounting. The main finding of the study is that while land, labor, and capital have statistically significant positive long-run effects on agricultural output, both the growth of the sector and the contribution of each factor to it have slowed over time. In particular, over the period 2009–2017, the growth of the sector was mainly contributed by TFP followed by capital and labor, while the contribution of land was negative. The results are robust to various econometric methods and specifications of agricultural productivity.

Probably the first issue for the policymakers' consideration is the reduced land area and hence, its diminished and even a negative contribution to the growth of the sector. The causes of this problem should be identified first, and effective measures should be taken accordingly.

Secondly, the government might want to raise the contribution of labor to the growth of the sector as it was found to be quite small. This can be done either increasing number of employed people or raising productivity of the employment in the sector.

The government should continue to promote investment in the sector, as capital and TFP have been the main factors for the sector's growth. To this end, the government can provide discounts and soft loans to farmers, and new financial instruments can also encourage private investment. Measures that lead to TFP growth should also be implemented, such as promotions for research and development, innovation, entrepreneurship, efficient use of production factors and other resources.

Finally, the authorities may wish to think about evaluating and monitoring the efficiency of the state programs as the growth of the sector and the contribution of the factors have slowed down over time whereas in the last decade, the sector was expected to grow more strongly, as many programs were implemented, and significant investments were materialized.

REFERENCES

ACEMOGLU, D., JOHNSON, S. and ROBINSON, J. A. 2005. Institutions as a fundamental cause of long-run growth. In: *Handbook of economic growth*. Volume 1(A). Elsevier, pp. 385–472.

ACOSTA, A. and LUIS, A. 2019. What is driving livestock total factor productivity change? A persistent and transient efficiency analysis. *Global Food Security,* 21: 1–12.

ACS, Z. J., ESTRIN, S., MICKIEWICZ, T. and SZERB, L. 2014. *The continued search for the Solow residual: the role of national entrepreneurial ecosystem*. IZA Discussion Paper No. 8652. IZA.

AERR. 2017. *Strategic Roadmap on production and processing of agricultural products in the Republic of Azerbaijan*. Azerbaijan Economic Reforms Review. Baku: Center for Analysis of Economic Reforms and Communication.

AGHION, P. and HOWITT, P. 1998. *Endogenous Growth Theory*. Cambridge, MA: MIT Press.

ALIYEV, I. 2008. *Rural-Urban Labor Migration in Azerbaijan*. Budapest: Central European University. Budapest.

ANTLE, J. M. 1983. Infrastructure and aggregate agricultural productivity: International evidence. *Economic Development and Cultural Change,* 31(3): 609–619.

APERGIS, N. and PAYNE, E. J. 2009. Energy consumption and economic growth: evidence from the Commonwealth of Independent States. *Energy Economics,* 31(5): 641–647.

APERGIS, N. and PAYNE, E. J. 2010. Renewable energy consumption and growth in Eurasia. *Energy Economics,* 32(6): 1392–1397.

ARASRM. 2016. *Azerbaijan Republic Strategic Road Map for the Production and Processing of Agricultural Products for 2016–2025*. Baku: ARASRM.

BAIG, M. B. and STRAQUADINE, G. S. 2014. Sustainable agriculture and rural development in the Kingdom of Saudi Arabia: implications for agricultural extension and education. In: *Vulnerability of Agriculture, Water and Fisheries to Climate Change*. Dordrecht: Springer, pp. 101–116.

BANERJEE, A., DOLADO, J. and MESTRE, R. 1998. Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of time series analysis,* 19(3): 267–283.

BROWN, R. L., DURBIN, J. and EVANS, J. M. 1975. Techniques for testing the constancy of regression relationships over time. *Journal of the Royal Statistical Society: Series B (Methodological)*, 37(2): 149–192.

CAMPOS, J., ERICSSON, N. R. and HENDRY, D. F. 2005. *General-to-specific modeling: an overview and selected bibliography*. FRB International Finance Discussion Paper Number 838. Board of Governors of the Federal Reserve System.

CASTLE, J. L., DOORNIK, J. A. and HENDRY, D. F. 2011. Evaluating automatic model selection. *Journal of Time Series Econometrics*, 3(1): 1–33.

CASTLE, J. L., DOORNIK, J. A. and HENDRY, D. F. 2021. Robust discovery of regression models. *Econometrics and Statistics*, In Press, Corrected Proof. DOI: https://doi.org/10.1016/j.ecosta.2021.05.004

CESD. 2015. *Evaluation and Modeling of Comparative Advantages in Agriculture in Azerbaijan.* Baku: Center for Economic & Social Development.

CHERIF, R. and AREZKI, R. 2010. *Development Accounting and the Rise of TFP*. International Monetary Fund, Working Paper No. 10/101. IMF.

CHOW, G. C. 1960. Tests of Equality between Sets of Coefficients in Two Linear Regressions. *Econometrica,* 28(3): 591–605.

COBB, C. W. and DOUGLAS, P. H. 1928. A theory of production. *The American Economic Review*, 18(1): 139–165.

COLLINS, S. M. and BOSWORTH, B. P. 1996. Economic growth in East Asia: accumulation versus assimilation. *Brookings papers on economic activity*, 2: 135–203.
CRRC. 2007. *Caucascus Research Resource Center Data Initiative* [online]. Available at: http://www.crrccenters.org [Accessed: 2022, May 15].
DESBOULETS, L. D. D. 2018. A review on variable selection in regression analysis. *Econometrics*, 6(4): 45.
DESTEK, M. A., OKUMUŞ, İ. and YILDIRIM, A. 2017. Tarımsal Katma Değer Üzerinde Hollanda Hastalığı Etkileri: Azerbaycan, Kazakistan, Kırgızistan ve Özbekistan için Bulgular. *Bilig*, 83: 225–239.
DICKEY, D. A., FULLER, W. A. 1981. The Likelihood Ratio Statistics for Autoregressive Time Series with a Unit Root. *Econometrica,* 49(4): 1057–1072. DOI: 10.2307/1912517
DIEWERT, W. E. 1988. *The early history of price index research*. Working Paper No. 2713. Cambridge, MA: National Bureau of Economic Research.
DIEWERT, W. E. 1992. The measurement of productivity. *Bulletin of Economic Research,* 44(3): 163–198.
DOORNIK, J. A. 2009. Autometrics. In: CASTLE, J. L. and SHEPHARD, N. (Eds.). *The Methodology and Practice of Econometrics: A Festschrift in Honour of David F. Hendry*. Oxford, UK: Oxford University Press, pp. 88–121.
DOORNIK, J. A. and HENDRY, D. F. 2009. *Modelling Dynamic Systems Using PcGive 14: Volume I*. OxMetrics 7. London: Timberlake Consultants.
DOORNIK, J. A. and HENDRY, D. F. 2018. *Empirical Econometric Modelling Using PcGive 14: Volume I*. London: Timberlake Consultants.
ENDERS, W. 2015. *Applied econometric time series*. 4th Edition. Print book.
ENDERS, W. and LEE, J. 2012a. A unit root test using a Fourier series to approximate smooth breaks. *Oxford bulletin of Economics and Statistics,* 74(4): 574–599.
ENDERS, W. and LEE, J. 2012b. The flexible Fourier form and Dickey-Fuller type unit root tests. *Economics Letters,* 117(1): 196–199.
ENGLE, R. F. and GRANGER, C. W. J. 1987. Co-Integration and Error Correction: Representation, Estimation, and Testing. *Econometrica*, 55(2): 251–276.
EPPRECHT, C., GUEGAN, D., VEIGA, Á. and CORREA DA ROSA, J. 2021. Variable selection and forecasting via automated methods for linear models: LASSO/adaLASSO and Autometrics. *Communications in Statistics-Simulation and Computation*, 50(1): 103–122.
ERICSSON, N. R. 2021. *Dynamic Econometrics in Action: A Biography of David F. Hendry*. International Finance Discussion Papers 1311. Washington: Board of Governors of the Federal Reserve System.
ERICSSON, N. R. and MACKINNON, J. G. 2002. Distributions of error correction tests for cointegration. *The Econometrics Journal*, 5(2): 285–318.
EVENSON, R. E. and MWABU, G. 2001. The effect of agricultural extension on farm yields in Kenya. *African Development Review*, 13(1): 1–23.
FARIDI, M. Z. and MURTAZA, G. 2013. Disaggregate energy consumption, agricultural output and economic growth in Pakistan. *The Pakistan Development Review*, 52(4): 493–516.
FELLONI, F., WAHL, T. and WANDSCHNEIDER, P. 2000. *Evidence of the effect of infrastructure on agricultural production and productivity: Implications for China*. Department of Agricultural Economics, Washington State University, Pullman, WA.
FUENTES, J. R. and MORALES, M. 2011. On the measurement of total factor productivity: A latent variable approach. *Macroeconomic Dynamics,* 15(2): 145–159.
FURUOKA, F. 2017. A new approach to testing unemployment hysteresis. *Empirical Economics*, 53(3): 1253–1280.
HARBERGER, A. C. 1998. A vision of the growth process. *American Economic Review,* 88(1): 1–32.
HASANLI, Y. and RAHIMLI, G. 2020. Estimation of Sectoral Elasticities of Substitution: Case of Azerbaijan. In: *Economic And Social Development: Book of Proceedings 3*, pp. 711–716.
HASANOV, F. 2013. Dutch disease and the Azerbaijan economy. *Communist and Post-Communist Studies,* 46(4): 463–480.
HASANOV, F. and SHANNAK, S. 2020. Electricity subsidies for agriculture in Saudi Arabia. Is that relevant to remove them? *Energy Policy*, 144: 111589.
HASANOV, F. J., LIDDLE, B., MIKAYILOV, J. I. *et al*. 2019. How total factor productivity drives long-run energy consumption in Saudi Arabia. In. SHAHBAZ, M. and BALSALOBRE, D. (Eds.). *Energy and Environmental Strategies in the Era of Globalization*. Springer, pp. 195–220.
HENDRY, D. F. 2020. *First In, First Out: Econometric Modelling of UK Annual CO2 Emissions: 1860–2017*. Nuffield College, University of Oxford.
HOROWITZ, J. K. and GOTTLIEB, J. 2010. *The role of agriculture in reducing greenhouse gas emissions.* Economic brief No. (EB-15). Economic research Service.
HUMBATOVA, S. I. and HAJIYEV, N. G. 2017. Two-factorial functional analysis of economic development in the regions of Azerbaijan. *Electronic journal of polish agricultural universities* 20(4): 03.

HUMBATOVA, S. I. and HAJIYEV, N. G-O. 2020. Investment and loaning in Azerbaijan agriculture. *Bulgarian journal of agricultural science*, 26(6): 1116–1128.
JOHANSEN, S. 1988. Statistical Analysis of Cointegration Vectors. *Journal of Economic Dynamics and Control*, 12(2–3): 231–254.
JOHANSEN, S. and JUSELIUS, K. 1992. Testing Structural Hypotheses in A Multivariate Cointegration Analysis of The PPP and the UIP for UK. *Journal of Econometrics*, 53(1–3): 211–244.
JOHNSON, J. M-F., FRANZLUEBBERS, A. J., WEYERS, S. L. *et al.* 2007. Agricultural opportunities to mitigate greenhouse gas emissions. *Environmental pollution,* 150(1): 107–124.
JONES, C. I. and ROMER, P. M. 2010. The new Kaldor facts: ideas, institutions, population, and human capital. *American Economic Journal: Macroeconomics,* 2(1): 224–245.
JORGENSON, D. W. and GRILICHES, Z. 1997. The Explanation of Productivity Change. *Review of Economic Studies*, 34(3): 249–283.
JUSELIUS, K. 2006. *The cointegrated VAR model: methodology and applications.* Oxford University Press.
MACKINNON, J. G. 1996. Numerical distribution functions for unit root and cointegration tests. *Journal of Applied Econometrics*, 11(6): 601–618.
MACKINNON, J. G., HAUG, A. A. and MICHELIS, L. 1999. Numerical distribution functions of likelihood ratio tests for cointegration. *Journal of Applied Econometrics*, 14(5): 563–577.
NARAYAN, P. K. 2005. The Saving and Investment Nexus for China: Evidence from Cointegration Tests. *Journal Applied Economics,* 37(17): 1979–1990.
NEHRU, V. and DHARESHWAR, A. 1993. A new database on physical capital stock: Sources, Methodology and Results. *Revista de análisis económico*, 8(1): 37–59.
OULTON, N. 2017. *The mystery of TFP.* Economic Statistics Centre of Excellence (ESCoE) Discussion Papers ESCoE DP-2017-02. Economic Statistics Centre of Excellence (ESCoE).
PAUSTIAN, K. *et al.* 2006. *Agriculture's role in greenhouse gas mitigation.* Pew Center on Global Climate Change.
PERRON, P. 1989. The Great Crash, the Oil Price Shock, and the Unit Root Hypothesis. *Econometrica,* 57(6): 1361–1401.
PESARAN, M. H. and SHIN, Y. 1999. *An Autoregressive Distributed Lag Modelling Approach to Co-integration Analysis*. Revised version of a paper presented at the Symposium at the Centennial of RagnarFrisch, The Norwegian Academy of Science and Letters, Oslo, March 3–5, 1995.
PESARAN, M. H., SHIN, Y. and SMITH, R. J. 2001. Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics*, 16(3): 289–326.
PHILLIPS, P. C. B. and HANSEN, B. E. 1990. Statistical inference in instrumental variables regression with I (1) processes. *The Review of Economic Studies,* 57(1): 99–125.
PHILLIPS, P. C. B. and LORETAN, M. 1991. Estimating Long-Run Economic Equilibria. *Review of Economic Studies*, 58(3): 407–436.
PHILLIPS, P. C. B. and PERRON, P. 1988. Testing for a Unit Root in Time Series Regression. *Biometrika*, 75(2): 335–346.
PRESCOTT, E. C. 1997. *Needed: A Theory of Total Factor Productivity*. Research Department Staff Report 242. Federal Reserve Bank of Minneapolis.
RAM, R. 1986. Government size and economic growth: A new framework and some evidence from cross-section and time-series data. *The American Economic Review,* 76(1): 191–203.
REIMERS, H. E. 1992. Comparisons of tests for multivariate cointegration. *Statistical Papers,* 33(1): 335–359.
REINSEL, G. C. and AHN, S. K. 1992. Vector autoregressive models with unit roots and reduced rank structure: estimation, likelihood ratio test, and forecasting. *Journal of Time Series Analysis,* 13(4): 353–375.
ROMER, P. M. 1986. Increasing returns and long run growth. *Journal of Political Economy*, 94(5): 1002–1037.
ROMER, P. M. 1990. Endogenous technological change. *Journal of Political Economy,* 98(5, Part 2): S71–S102.
SEHHADJI, A. 1999. *Sources of economic growth: An extensive growth accounting exercise.* IMF working Paper WP/99/77. IMF.
SHAHBAZ, M., LOGANATHAN, N., SBIA, R. and AFZA, T. 2015. The effect of urbanization, affluence and trade openness on energy consumption: A time series analysis in Malaysia. *Renewable and Sustainable Energy Reviews,* 47: 683–693.
SICKLES, R. C. and ZELENYUK, V. 2019. *Measurement of Productivity and Efficiency*. Cambridge University Press. DOI: 10.1017/9781139565981
SMITH, P., MARTINO, D., CAI, Z. *et al.* 2008. Greenhouse Gas Mitigation in Agriculture. *Philosophical Transactions of The Royal Society B: Biological Sciences*, 363(1492): 789–813.

SOLOW, R. M. 1955. The Production Function and the Theory of Capital. *Review of Economic Studies*, 23(2): 101–108.
SOLOW, R. M. 1957. Technical change and the aggregate production function. *Review of Economics and Statistics*, 39(3): 312–320.
SOYTAS, U. and SARI, R. 2006. Can China contribute more to the fight against global warming? *Journal of Policy Modeling,* 28(8): 837–846.
SOYTAS, U. and SARI, R. 2007. The relationship between energy and production: evidence from Turkish manufacturing industry. *Energy Economics,* 29(6): 1151–1165.
SOYTAS, U., SARI, R. and BRADLEY, E. T. 2007. Energy consumption, income, and carbon emissions in the United States. *Ecological Economics,* 62(3–4): 482–489.
SPSEDRA. 2014. *State Programme on Socio-Economic Development of Regions of the Republic of Azerbaijan for 2014–2018 years*. Baku.
SSCRA. 2019. *The State Statistical Committee of the Republic of Azerbaijan*. Baku.
THE ECONOMIST INTELLIGENCE UNIT. 2019. *Global Food Security Index 2019*. The Economist Intelligence Unit and Corteva Agriscience.
TIMMER, C. P. and BLOCK, S. A. 1994. *Agriculture, and economic growth: Conceptual Issues and the Kenyan Experience*. Harvard Institute for International Development (HIID) Papers 294430, Harvard University, Kennedy School of Government.
VAFA, J., KIM, K. D. and LEE, B. H. 2020. Analysis of Factors Affecting Economic Growth and Productivity in Azerbaijan, Belarus, Georgia, Moldova, and Ukraine. *Journal of Agricultural, Life and Environmental Sciences*, 32(Special Issue): 281–296.
VAN BERKUM, S. 2017. *Market and competitiveness analysis of the Azerbaijan agricultural sector: an overview*. Wageningen University & Research. Department of LEI International Policy
WEITZMAN, M. L. 1970. Soviet postwar economic growth and capital-labor substitution. *The American Economic Review,* 60(4): 676–692.
WORLD BANK. 2018. *World Development Indicators 2018*. World Bank.
WORLD BANK. 2021. *World Development Indicators 2021*. World Bank.
WORLD BANK. 2020. Agriculture & Rural Development. *The World Bank* [Online]. Available at: https://data.worldbank.org/topic/agriculture-and-rural-development?locations=AZ [Accessed: 2022, May 20].
YAVAS, U. and TUNCALP, S. 1983. Foreign product images in Saudi Arabia. *International Advertiser*, 4(5): 8–10.
ZELENYUK, V. 2014. Testing Significance of Contributions in Growth Accounting, with Application to Testing ICT Impact on Labor Productivity of Developed Countries. *International Journal of Business & Economics,* 13(2): 115–126.
ZHANG, W. and YANG, S. 2013. The influence of energy consumption of China on its real GDP from aggregated and disaggregated viewpoints. *Energy Policy,* 57: 76–81.

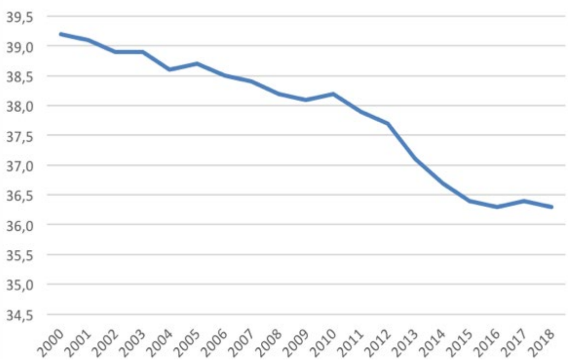
Contact information

Fakhri J. Hasanov: fakhri.hasanov@kapsarc.org
Elchin Suleymanov: elsuleymanov@beu.edu.az
Heyran Aliyeva: heyran.aliyeva@kapsarc.org (corresponding author)
Hezi Eynalov: heynalov@beu.edu.az
Sa'd Shannak: sshannak@hbku.edu.qa

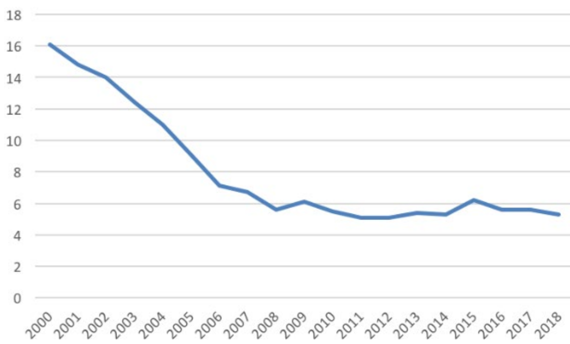
APPENDIX A.

AN OUTLOOK OF THE AZERBAIJANI AGRICULTURE SECTOR

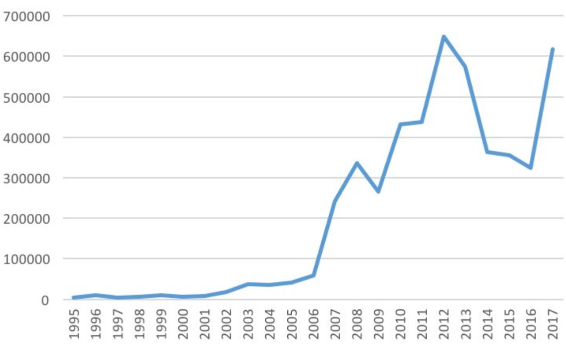
Azerbaijan is one a rich country in terms of the natural resources, in particular oil and natural gas in Caucasus. Development of the oil industry in the early twentieth century has increased the investment in the oil sector, and this also spilled over to the agriculture sector in the country. The country lost its status as an agrarian nation after the "Contract of the Century" which was signed in 1994 to support oil production and its transportation to the world markets because of the oil and related chemical industry established during the last century (CESD, 2015). The share of agriculture value added has been around 5–6% in GDP in the last decade (See Fig. A.1B). Despite its low share in GDP, it is possible to denote that agricultural activity has a traditional role in Azerbaijani culture as we see a rapid growth in the development of viticulture in the western part of Azerbaijan produced high-quality wines. Additionally, oil tycoons (H. Z. Taghiyev, Nobel's brothers, Rothschilds brothers, etc.) laid out major investments in the development of weaving that has contributed to the development of cotton, silk, and wool production. Agriculture is the number one in the Azeri economy as more than 36% of the total employment on average belonged to the sector during 1995–2018 (Fig. A.1A). This shows how the sector is important in reducing unemployment in the country. Sector's employment grew only by less than 13% from 1.6 million persons in 1999 to 1.8 million persons in 2018 while the employment in other sectors of the economy grew significantly in the same period (e.g., those in construction and information-communication sectors grew by 124.2% and 148.2%, respectively). Although the agricultural employment share in total employment jumped from 30.1% in 1995 to 41.5% in 1999, it kept declining since then and was 36.3% in 2018. As a main reason of this decrease, it is worth stating that urbanization has accelerated since 2000 and rural population has been decreasing (World Bank, 2020). Fig. A.1C shows that the investments in agricultural sector had been increasing until 2012, with the sharp increases since 2007. Then there are dramatic declines until 2016 and then a recovery in 2017. Both the sharp increases and decreases were mainly caused by the oil price increases and decreases, respectively, which were mirrored in the oil revenues, government spending and economic activity of the country. Apparently from Fig. A.1D, the agriculture export dramatically increased in 2008 and decline in 2009. The increase was driven



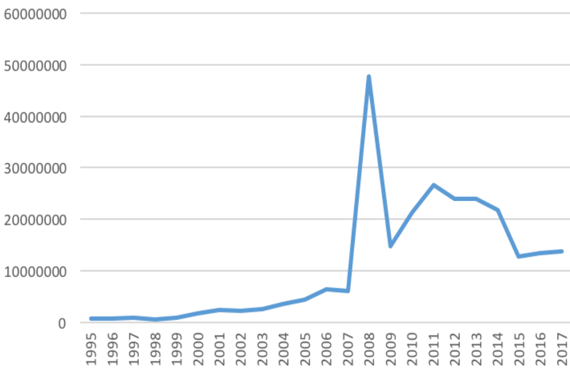
A.1A: Agricultural employment share in total (%)



A.1B: Agriculture value added share in GDP, %



A.1C: Investments in agriculture, forestry, and fishing (thousands of Manat)



A.1D: Exports in agriculture, forestry and fishing (thousands of USD)

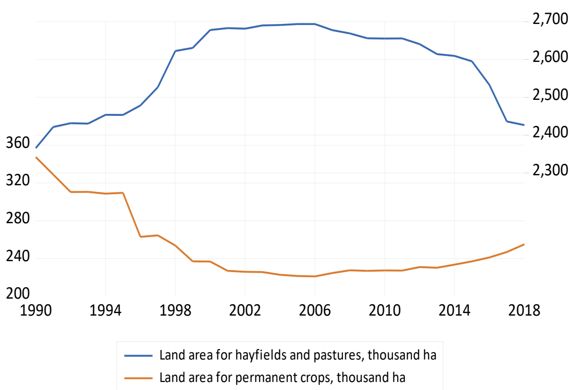
A.1: Statistics on agriculture, forestry, and fishing in Azerbaijan
Source: The State Statistical Committee of the Republic of Azerbaijan, 2019

by high global economic demand in the pre-crisis period and the decrease mainly was driven by the global financial crisis. The agricultural export was 750 million USD in 2018, accounting for 53.5% of the total non-oil exports.

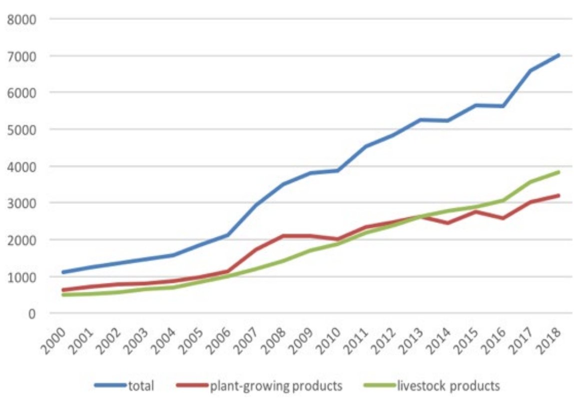
Agriculture is one of the most important sectors in the development of the non-oil economy in Azerbaijan. Azerbaijan's rich agriculture areas and regions with different climate zones make it possible to grow quality and wide range products. Two climatic zones and nine climatic types of the world are available in Azerbaijan. The variety of climate makes possible to grow various sorts of harvest. Azerbaijan's main agricultural products are wheat, tobacco, tea, olive oil, fruit, and vegetables. The country has enough potential to produce grain and satisfy internal demand.

Fig. A.2 illustrates that the land area for permanent crops and that for hayfields and pastures oppositely evolved to each other, which may imply that farmers expanded the former by means of reducing the latter over time. Moreover, statistics show that the plant production were dominant in total agricultural production in 1990's, whereas there was a shift to the livestock production (Fig. A.2B). Total agricultural production was 7 billion AZN in 2018 and more than 55% of it established by the cattle-breeding products. It is noteworthy to mention that topsoil and vegetation of Azerbaijan is peculiar due to its variety.

Agro-industry plays a crucial role by generating 2.7 billion USD that equals to 41% of manufacturing output. Main areas are the processing of meat and dairy products and canning of fruit and vegetables. Agricultural holdings are 99.8% private, out of which 66.8% are family farms, 32.8% are engaged as subsistence farming, and 0.2% are run by agricultural enterprises. Fig. A.2C shows the breakdown of gross output of agriculture (GOA) in terms of types of farms. Notably, the private owned and family-based farms have a very large share in the total output although this share slightly declined towards the end of the period. Numerically, 91% of GOA were produced by individual entrepreneurs, family and households and the rest was produced by agricultural enterprises and other organizations in 2018.

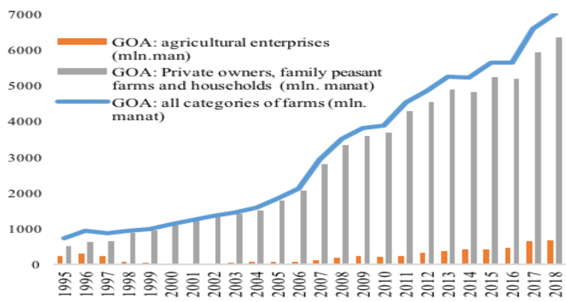


A.2A: Land area for permanent crops and hayfields and pastures, 1000 ha



A.2B: Gross output of agriculture, actual prices, million Manats

Source: The State Statistical Committee of the Republic of Azerbaijan, 2019



A.2C: Gross output of agriculture, million Manats

Source: The State Statistical Committee of the Republic of Azerbaijan, 2019. https://azstat.org/statHtml/statHtml.do?orgId=994&tblId=DT_BB_008&language=en&conn_path=I3

A.2D: Agricultural raw materials trade

A.2: Statistics on Agricultural Land and Activity

In terms of trade, Azerbaijan is a net-importer of several agricultural products such as cereals (wheat, rice and maize), potatoes (used to be a net-exporter until 2011), meat (except poultry), dairy products, fish and vegetables oils. The country is a net-exporter of fruits and berries, and all kinds of vegetables. Fig. A.2D shows the trade of agricultural raw products over years. The overall agricultural net-trade position of the country is negative (Van Bekum, 2018). The country is also a net importer of food products, but it possesses diverse topographic and climatic zones, which allow for the agricultural production of a wide range of plants and animals including products of fisheries and bee keeping. The major problem lies in low agricultural productivity.

Azerbaijan also has great prospects for foreign trade in agricultural and food products. The country is a natural bridge between Europe and Asia for its geographical location and this makes it easier for Azerbaijan to access the giant markets with more than 600 million consumers, such as the CIS, Middle East and Central Asia. 1,400,000 hectares of 1,900,000 hectares of land in Azerbaijan are fully equipped with modern irrigation systems. This factor reaffirms the existence of necessary conditions in our country for high productivity. However, besides all these advantages, the main foodstuffs in the country's imports indicate that foodstuffs are dependent on imports, and it is crucial to reduce dependence and to satisfy domestic demand with domestic production. That is, productivity should be at least twice as high as it is now.

"Strategic Roadmap for the Production and Processing of Agricultural Products in the Republic of Azerbaijan" approved by the Decree of the President of the Republic of Azerbaijan dated December 6, 2016 has been prepared to create a favorable environment for the formation of a competitive agricultural production and processing sector, strengthening food security, diversifying the economy and improving social welfare in rural areas. According to this document, it is envisaged to implement 9 strategic goals to create a favorable environment for achieving the formation of a competitive agricultural production and processing sector, based on sustainable development principles in the country in 2016–2020.

APPENDIX B.

ADDITIONAL METHODS FOR ROBUSTNESS CHECK

For robustness, we also use two more methods, in addition to VECM and ADL, to test cointegration and estimate level relationship. The first one is the ARDLBT (Autoregressive Distributed Lagged Bounds Testing) method developed by Pesaran and Shin (1999) and Pesaran *et al*. (2001). The second one is the FMOLS (Fully Modified Ordinary Least Squares) method developed by Phillips and Hansen (1990), Phillips and Loretan (1991), which estimates the level relationship and then performs the residual-based cointegration test (Engle and Granger, 1987). For both tests, the null hypothesis is the absence of cointegration. Although it is well known that the Engle-Granger cointegration method has some limitations compared to its counterparts, we will use it just to compare results from it with those from the other two methods for robustness purposes. We do not describe the methods here as they are very widely used in empirical analyses and interested readers can refer to the references mentioned above.

Small Sample Bias Corrections in Cointegration Tests

To ensure our inferences about the cointegration properties of the variables are robust, we apply small sample bias correction for the Trace and Max-Eigenvalue statistics in Johansen cointegration test using the method suggested by Reinsel and Ahn (1992) and Reimers (1992). We also use a small sample bias correction in the ARDL bounds testing for cointegration by using Narayan (2005) critical values, which are tabulated using small number of observations. Lastly, in FMOLS-based Engle-Granger cointegration test and estimation, we consider degree of freedom adjusted estimates.

APPENDIX C.

EMPIRICAL ANALYSIS

C.1. The Unit Root Tests Results

We check the stochastic properties of the level and first difference of *ypl*, *cfpl*, and *lapl* using the ADF and PP tests. Tab. C.I documents the results of the unit root test.

The results of the ADF and PP tests reported in Panels A and B of Tab. C.I are consistent with each other and clearly suggest that *ypl*, *cfpl*, and *lapl* are unit root processes. This is because the sample t-statistics are smaller than critical test statistics in absolute terms as the upper part of the table records meaning that the null hypothesis of unit root cannot be rejected. However, for the first difference of the variables, the sample statistics are greater than the critical values at the 1% significance level in absolute terms as the lower part of the table reports suggesting that they are stationary processes. To conclude the unit root exercise, all the variables, namely *ypl*, *lapl* and *cfpl* have unit root at their level but they are stationary at their first differences. In other words, they follow I(1) process.

C.I: The results of the unit root test

Variable	Panel A: The ADF test					Panel B: The PP test			
	Test value	C	T	None	k	Test value	C	t	None
ypl	-2.59		x		1	-1.63		x	
lapl	-2.90		x		0	-2.69		x	
cfpl	-1.81		x		0	-1.81		x	
Δ*ypl*	-3.25***			x	0	-3.25***			x
Δ*lapl*	-5.14***	x			1	-5.14***			x
Δ*cfpl*	-4.37***			x	0	-4.38***			x

Notes: ADF and PP denote the Augmented Dickey-Fuller and Phillips-Perron tests, respectively. Maximum lag order is set to one and optimal lag order (k) is selected based on Schwarz criterion in the tests; ***, ** and * indicate rejection of the null hypotheses at the 1%, 5% and 10% significance levels, respectively; The critical values for the tests are taken from MacKinnon (1996). UR test equation includes one of the three options: intercept (C), intercept and trend (t) and none of them (None). x indicates that the corresponding option is selected in the UR test equation based on the statistical significance. Estimation period is 1997–2017.

C.2. Cointegration Test and Long-run Estimations Results

C.2.1. The Results of the Johansen Cointegration Analysis

Following the methodological footsteps that Juselius (2006) describes inter alia, we first estimate a Vector Auto regressive model (VAR) for equation (4).[12] In doing so, we set two-lag order as a maximum for our endogenous variables to save more degree of freedom for estimations as we have a small sample. The *lag exclusion test* indicates that two lags cannot be reduced to one lag without information lose while all the five criteria from the *lag order selection* test suggest two lags as an optimal.[13] The Lagrange Multiplier test indicates that VAR residuals do not have serial correlation problem at the 5% significance level. Additionally, the residuals are normally distributed, and their variance is homoscedastic. Moreover, the VAR satisfies the stability condition as no characteristic root is out of the unit circle.[14]

Hence, we transformed the estimated VAR model to a VEC model to perform cointegration test and estimate level relationship. Because of the reasons below we did not consider the results from the cointegration test options of (i) No intercept and no trend in the long-run/level part of VEC; (ii) Intercept in the long-run/level part of VEC but not in short-run part and (v) Intercept and quadratic trend in the long-run/level part of VEC. Option (i) assumes no intercept in long-run/level relationship of agriculture productivity, which is inconsistent with the theory of production. Option (ii) assumes that growth rate of agriculture productivity is zero, but this is not the case from the graphical illustration of the variable. Option (v) assumes quadratic trend in *ypl*, but it is not the case from the unit root test results. Further, we did not consider option (iv) Intercept and trend in the level equation because the normalization of the cointegration vector for *ypl* yields negative coefficients for *lapl* and time trend as well as statistically insignificant SoA for the short-run equation of *ypl*, which all of them are not plausible. Thus, we ended up with option (iii) Intercept but not trend in the long run/level part of the VEC model. Tab. C.II reports the sample

12 Our endogenous variables are *ypl*, *lapl*, and *cfpl*, while the exogenous variables are intercept, time trend, and *DTB07* trend break dummy in the VAR specification. As Panel A of Fig. 1 illustrates, *ypl* has a break in its trend starting in 2007. To capture the possible long-run effects of this, we include a trend break dummy variable (*DTB07*), taking zero until 2006 and t-2006 in 2007 and thereafter, where t > 2006 in the level estimations. Perron (1989) discusses in detail types of structural breaks and constructing dummy variables to capture them. We also estimated a VAR specification, where *DTB07* trend break dummy is considered as an endogenous variable alongside the other three economic variables (Juselius, 2006 provides a very comprehensive discussion of including dummy variables in level relationship in Chapter 2 and hence we do not discuss details of specifying such a VAR model). The results of the estimations, post-estimation and stability test are similar to those from the VAR estimates, where *DTB07* is treated as an exogenous variable.

13 Although both the lag determination tests favor two-lag order as an optimal, we also estimated VAR with one lag order. In that case, VAR's residuals are still well-behaving, the transformed VEC indicates one cointegrating relationship among the variables in most test options and estimated long-run and SoA coefficients are statistically significant and economically meaningful. However, we preferred VAR with two lags to that with one lag, mainly because VAR with one lag yields VEC with zero lag. Such a VEC model without autoregressive terms implies that the short-run dynamics of the endogenous variables depend only on the equilibrium correction term with one lag but not lagged terms of any variables, which is hard to believe.

14 All the discussed test results on the estimated VAR are not reported here to conserve the space but they are available from the authors upon request.

C.II: Johansen cointegration test and estimation results

Panel A: Cointegration test			
Null hypothesis:	$r = 0$	$r \leq 1$	$r \leq 2$
λ_{trace}	57.11***	28.11*	11.95
λ^{a}_{trace}	40.79	20.08	8.54
λ_{max}	29.00**	16.16	11.83
λ^{a}_{max}	20.71	11.54	8.45

Panel B: Long-run estimation		
Regressor	Coefficient	Standard Error
lapl	0.82***	0.13
cfpl	0.16***	0.03
*DTB*07	0.04***	0.01
C	-0.14	
SoA	-1.01***	0.40

Notes: *r* is the rank of Π matrix, i.e., number of cointegrated equations; λ^{a}_{trace} and λ^{a}_{max} are the small sample adjusted version of the Trace and Max eigenvalue statistics; ***, ** and * denote statistical significance at the 1%, 5% and 10% levels, respectively; Critical values for the cointegration test are taken from MacKinnon *et al.* (1999). Estimation period: 1997–2017.

Trace and Max-Eigenvalue cointegration test statistics before and after small sample correction from option (iii) and estimated long-run and SoA coefficients.

According to Panel A of Tab. C.II, there is only one cointegrating relationship between the variables in equation (4) and no cointegrating relationship after the Trace and Max-Eigenvalue statistics are adjusted for small sample bias. The key takeaway for us is that there is no strong reason to believe that the variables establish more than one cointegrating relationship. Johansen (2002) discusses that the Trace and Max-Eigenvalue are usually failing to reject the null hypothesis of no cointegration in the small sample sizes. Besides, from the theoretical standpoint, having no relationship does not seem plausible, as the theory of production articulates a long-run relationship between output and its factors. Lastly, the cointegration test results from the ADL, ARDL and FMOLS estimations indicate that the variables are cointegrated. Panel B of Tab. C.II reports that the estimated long-run elasticities of *YPL* with respect to *LAPL* and *CFPL* are positive, as theoretically expected, and statistically significant. The trend break dummy is positive and equilibrium correction term (ECT) with one lag has an expected negative sign, and both variables are statistically significant.

The null hypothesis that *lapl* is weakly exogeneous cannot be rejected as the Chi-squared sample values of 0.92 from the test is smaller than the corresponding critical value. The Chi-squared sample value from the same test for *cfpl* is 0.29 indicating weak exogeneity of the variable. Weak exogeneity of the explanatory variables allows us using single equation methods such as ADL, ARDL.

C.2.2. The Cointegration Analysis Using ADL in the Framework of Gets With Autometrics

Selecting regressors in the general unrestricted model (GUM)

We follow Section 6 of Hendry (2020) and Castle *et al.* (2021) to perform general to specific modeling strategy (*Gets*) using *Autometrics* with super saturation in PcGive toolbox in OxMetrics 8.0 (Doornik, 2009, chap. 4; Doornik and Hendry, 2009, 2018). Super saturation covers impulse-indicator saturation, change in impulse-indicator saturation, and step-indicator saturation in our case. Key advantage of the super saturation is that it can capture a one-time jump or drop, blip, and level shift in the development of *ypl*. First, we formed the general unrestricted ADL specification of *ypl* with one lag of all variables and contemporaneous values of the explanatory variables, *lapl, cfpl* and *DBT07*.[15] It is important to make sure that GUM is well-behaved in terms of post estimation tests before starting a journey from unrestricted to final conditional specification (see e.g., Campos *et al.*, 2005; Castle *et al.*, 2021). In this regard, our estimated GUM specification successfully passes residuals diagnostics tests of autocorrelation, ARCH, normality, heteroscedasticity as well as functional misspecification. Also, the recursive estimation tests do not show any serious instability issues with the specified GUM.

15 Initially, we built the general unrestricted ADL specification of *ypl* with two lags of all variables and contemporaneous values of the explanatory variables, *lapl, cfpl* and *DBT07*. Time trend is also included just to check whether it can provide additional information in explaining *ypl*. We noticed that all the second lags of the explanatory variables and time trend are highly insignificant even if we consider their significance separately at a time. Hence, we make our general unrestricted specification parsimonious by removing the second lags and time trend from the specification as this provides us with some more degree of freedom, which is important for efficient estimations given we have 21 annual usable observations. The other thing to mention is that we included *DBT07* in the general unrestricted ADL model based on our prior information (coming from the economic history of Azerbaijan and showed up in Fig. 1) that there is a break in the development trend of *ypl*, our dependent variable.

Selecting regressors in the final conditional ADL specification and implementing cointegration

In the next step, we retained (fixed) all the regressors in the GUM and ran the *Autometrics* option of *Large residuals* with the target size of 0.01 (small), i.e., 1% significance level to examine whether the GUM takes any impulse indicators. The purpose is to make sure that any significant outliers and or breaks in the development paths of *ypl* are captured by the specified GUM. Autometrics did not pick up any impulse indicators even after trying the target sizes of 0.025 (medium), 0.05 (standard). Also, we ran Autometrics option of *Saturation estimation* with the target size of 0.001 (tiny) on the GUM by restricting (fixing) all the regressors. In the *Saturation estimation* option, we selected impulse-indicator saturation, change in impulse-indicator saturation, and step-indicator saturation to capture outliers and breaks that can exists in data. *Autometrics* did not pick up any impulse indicators again. This might indicate that specified GUM is quite representative in capturing developments in *ypl*. In the last step, we unrestricted (unfixed) all the regressors except constant term and ran the *Autometrics* option of *None* with the target size of 0.10 (huge) on the GUM.[16] The purpose of this run is to let *Autometrics* retain or drop economic variables to end up with the final conditional specification. It dropped only the lagged value of *cfpl*. The final conditional ADL specification and its port-estimation test results are reported in Tab. C.III.

C.III: Final ADL specification, test results and long-run coefficients

Panel A: Selected final ADL specification		
Regressor	Coefficient	Std. Error
ypl_{t-1}	0.37**	0.15
$lapl_t$	1.02***	0.16
$lapl_{t-1}$	-0.48**	0.20
$cfpl_t$	0.08***	0.03
$DBT07_t$	0.20**	0.08
$DBT07_{t-1}$	-0.17**	0.07
C	-0.23	0.17
Panel B: Residual diagnostics, misspecification and cointegration tests results		
Statistic	Sample Value	Probability
$F_{AR}(2,12)$	0.83	0.46
$F_{ARCH}(1,19)$	0.04	0.85
F_{HETR} (11,9)	1.68	0.22
$\chi^2_N(2)$	4.23	0.12
$F_{Reset}(2,12)$	1.63	0.24
Panel C: Long-run coefficients		
Regressor	Coefficient	Standard Error
$lapl_{t-1}$	0.86***	0.23
$cfpl_t$	0.13***	0.04
$DBT07_t$	0.03***	0.01
C	-0.37*	0.21
$\chi^2(3)$	27.31	0.00
t_{URT}	-4.18*	

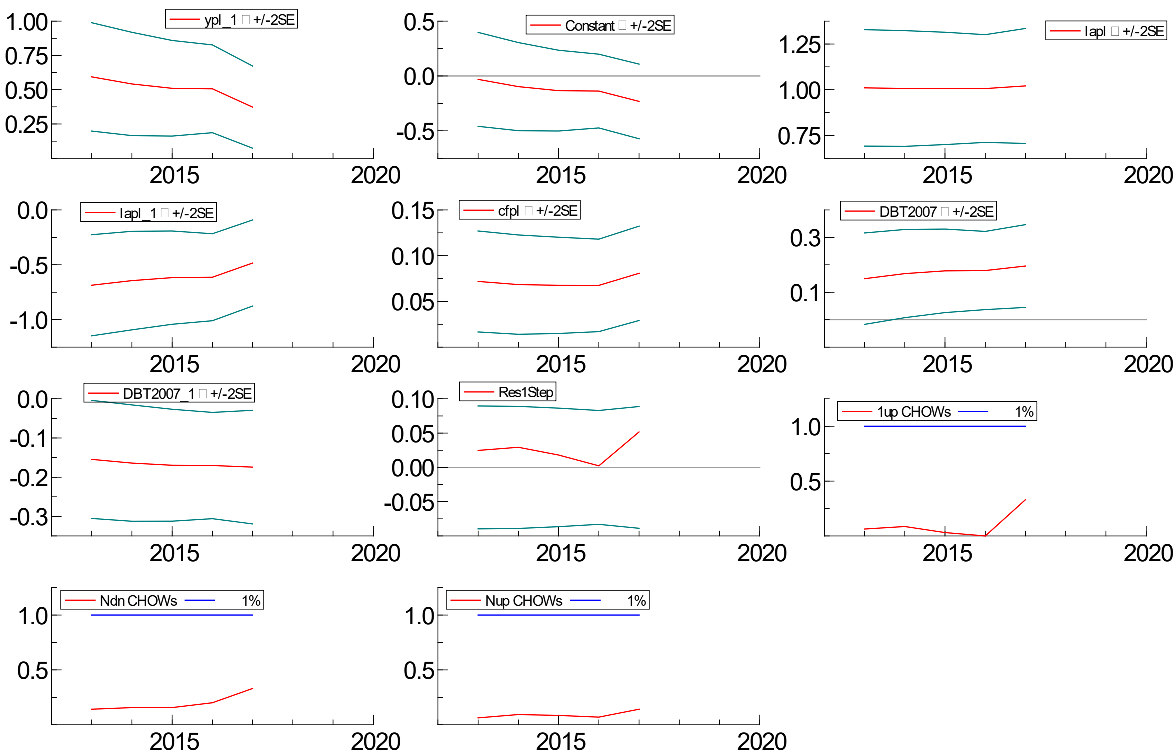
Notes: *ypl* is the dependent variable in the estimations; F_{AR}, F_{ARCH}, F_{HETR} and F_{Reset} denote *F* statistics to test the null hypotheses of no autocorrelation, no autoregressive conditioned heteroscedasticity, no heteroscedasticity in the residuals and no functional form misspecification, respectively; χ^2_N indicates the Chi-squared statistic to test the null hypotheses of normal distribution of the residuals. *, **, *** indicate statistical significance at the 1%, 5%, and 10% levels, respectively. Standard error of regression = 0.044. Estimation period: 1997–2017.

Apparently from Panel A all the retained regressors in the final conditional ADL specification are statistically significant and theoretically interpretable. Panel B presents the residuals of the specification are well-behaved and the specification does not have any functional misspecification issue. Also, we checked the stability of this specification using a set of tests. The test results are graphically illustrated in Fig. C.1 and do not show any serious evidence of instability.

The coefficient stability test shows that all the recursively estimated coefficients of the regressors (the first seven graphs, except the second one for constant term) are statistically significant. Additionally, the confidence interval of the recursively estimated residuals (the eighth graph) contains the zero-line indicating that the residuals are statistically insignificant and close to zero. Moreover, 1-step Chow test, Breakpoint Chow test and Forecast Chow test (Chow, 1960; Brown *et al.*, 1975) show no sign of instability as all the red lines are far below the blue lines (the last three graphs). Lastly, standard error of regression is reduced from 0.046 in the GUM specification to 0.044 in the final specification.

We solved the final conditional ADL specification in Panel A for the long-run static case. Panel C of the table reports the obtained long-run coefficients and their standard errors. Apparently, the first three coefficients are statistically significant at 1% significance level while constant is statistically significant at 10% significant level. However,

16 We fixed only the Constant term as it is dictated by the theory of production function. The reason for preferring the target size of 0.10 is that tighter target sizes drop autoregressive term of the dependent variable, which is inconsistent with the essence of ADL modeling and hence causes finding no cointegration.



C.1: Recursive estimation test results

this t-test based statistical significance might be unreliable as the variables are non-stationary. Therefore, we performed joint significance of the coefficients using the Wald test. The calculated Chi-squared value of 27.31 is greater than the corresponding critical value at 1% significance level. Hence, the null hypothesis that the coefficients are jointly zero can be rejected in favor of the alternative hypothesis of they are not jointly zero. We lastly, performed the cointegration test to examine whether the variables establish a long-run relationship or the obtained coefficients in Panel C are spurious. t-test indicates cointegration when the cointegration space is normalized for *ypl* as the sample value of -4.18 is greater than the corresponding corrected critical value of -3.91 in absolute terms in the case of three regressors, constant and 25 observations at the 5% significance level from Banerjee *et al.* (1998). Hence, it is concluded that the obtained coefficient from the level relationship in Panel C are not spurious and can be used for discussion or growth accounting purposes.

C.3. Robustness Check Results: Using ARDLBT and FMOLS for the Long-run Analysis

In this robustness exercise, we checked that which extent the long-run relationship between the agriculture productivity and the explanatory variables, including estimated numerical values of the coefficients, which we found in the previous section, can change. For this, we employed two other methods - the ARDL and FMOLS to perform cointegration test and estimate parameters of the level relationship.[17]

In ARDL estimation, we considered the maximum lag order of one and the Schwarz information criterion to specify the optimal lag length as we have small number of observations (see discussions in Pesaran and Shin, 1999; Pesaran *et al.*, 2001 inter alia).[18] Eight different ARDL specifications are estimated using different combinations of lagged and contemporaneous values of the variables and *ARDL(1,1,0,1)* is selected as a final specification based on the Schwarz information criterion.[19] Tab. C.IV documents the derived level relationship from the selected specification and test results.

17 We can perform the ARDL estimations and bounds test for cointegration as our dependent variable is a unit root process and none of our explanatory variables is I(2).

18 We also estimated the unrestricted ARDL specification with the maximum lag order of two, that is, *ARDL(2,2,2,2)*. However, none of the second lags of the variables was statistically significant.

19 To capture the possible long-run effects of the trend break dummy variable, DTB07, we included it in the level part of the ARDL specifications.

C.IV: ARDL estimation and test results

Selected specification:	ARDL(1,1,0,1)	
Panel A: Residual diagnostics, misspecification and cointegration tests results		
Statistic	Sample Value	Probability
$F_{SC}(2)$	0.83	0.46
$F_{ARCH}(2)$	0.10	0.90
F_{HETR}	1.13	0.40
JB_N	1.01	0.60
F_{FF}	3.47*	0.09
F_W	7.40***	
Panel B: Estimated long-run elasticities and SoA		
Regressor	Coefficient	Standard Error
lapl	0.86***	0.23
cfpl	0.13***	0.04
*DTB*07	0.03***	0.01
C	-0.37*	0.21
SoA	-0.63***	0.09

Notes: *ypl* is the dependent variable in the estimations; F_{SC}, F_{ARCH}, F_{HETR}, F_{FF} and F_W denote F statistics to test the null hypotheses of no serial correlation, no autoregressive conditioned heteroscedasticity, no heteroscedasticity in the residuals and no functional form misspecification and no cointegration in the Wald test, respectively; JB_N indicates the Jarque-Bera statistic to test the null hypothesis of normal distribution of the residuals. *, **, *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. Estimation period: 1997–2017.

Panel A of the table reports that the selected specification passes successfully all the post-estimation tests of residual diagnostics as well as the misspecification test. Additionally, the specification rejects the null hypothesis of no cointegrating relationship among the variables from the bounds test as the F sample value of 7.40 is larger than the upper bound critical value of Pesaran *et al.* (2001), which is 4.66 at the 1% significance level.[20] As a small sample bias correction to the cointegration test results, we also considered the critical values from Narayan (2005). The sample value is still greater than the respective upper bound critical value of Narayan (2005), i.e., 5.97 at the 1% significance level.[21] Panel B of the table reports that the signs of the SoA and long-run coefficients are theoretically coherent, and they are statistically significant. Note that expectedly, their magnitudes are identically the same as those obtained from the ADL estimation in Tab. C.III and quite close to those obtained from the VEC estimations reported in Tab. C.II.

C.V: FMOLS estimation and test results

Panel A: Cointegration test results			
Statistic	Sample Value	Statistic	Sample Value
EG_τ	-4.40*	EG_Z	-20.01*
EG_τ^α	-4.28*	EG_Z^α	-20.01*

Panel B: Estimated long-run coefficients		
Regressor	Coefficient	Standard Error
lapl	0.82***	0.14
cfpl	0.07**	0.02
*DTB*07	0.03***	0.00
C	-0.67***	0.13

Notes: *ypl* is the dependent variable in the estimation; EG_τ and EG_Z are the Engle-Granger tau- and z-statistics, respectively; EG_τ^α and EG_Z^α are the degree of freedom adjusted versions of the statistics; *, **, *** indicate statistical significance at the 10%, 5% and 1% levels, respectively. *DTB*07 is included in the level equation; Estimation period: 1997–2017.

We documented the results of the FMOLS estimations and associated the Engle-Granger cointegration test in Tab. C.V.

Panel A of the table reports that the sample values of the *tau* and *z* statistics of the Engle-Granger test are greater than the critical values of the test from MacKinnon (1996) in absolute terms at the 10% significance level. Even, the adjusted sample statistics are still greater than the respective critical values. These indicate that the null hypothesis of no cointegration can be rejected, and it can be concluded that the variables establish a long-run relationship. Panel B of the table reports that the estimated long-run coefficients are all positive and statistically significant. The magnitudes of the coefficients are not so far from those obtained from the ADL, ARDL and VEC estimations.

Thus, the robustness checks performed in this subsection conclude that agricultural productivity establishes a long-run relationship with per capita land and capital with certain magnitudes of their elasticities, regardless of the different methods used, whether system-based, single equation-based, or residual-based. This gives us a good basis to rely on the estimates of ADL, our main method, and to use them for the TFP and growth accounting calculations.

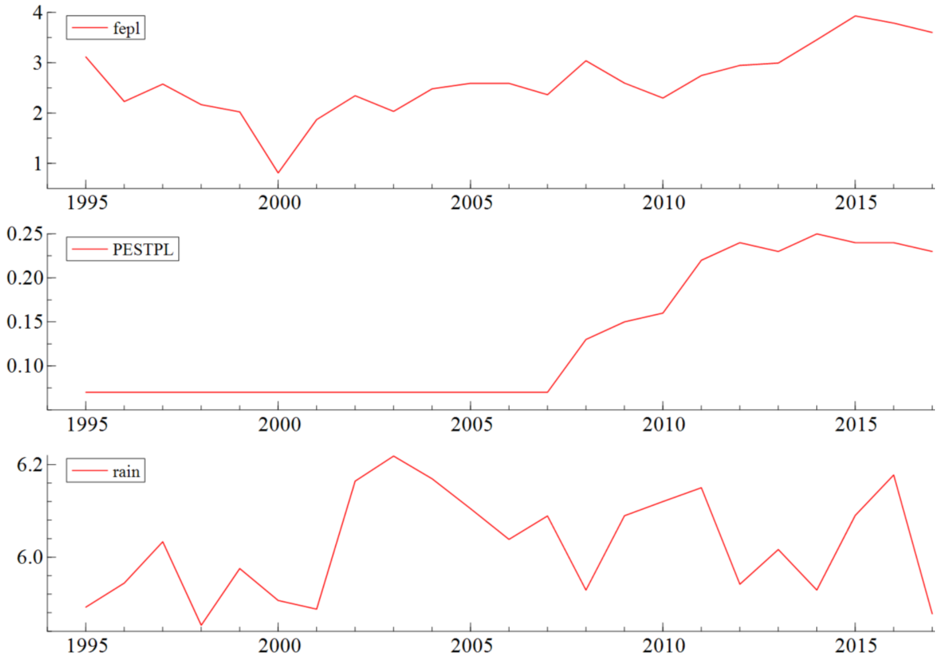
20 The upper bound critical value of Pesaran *et al.* (2001) at the 1% significance level is from the combination of three regressors and intercept is included in the long-run equation.

21 The upper bound critical value of Narayan (2005) at the 1% significance level is from the combination of three regressors, 30 observations, and intercept is included in the long-run equation.

C.4. Robustness Check Results: Using Extended Specification of the Agriculture Productivity

In this section, we extended equation (4) with other variables and apply estimation and testing to the extended specification to make sure that the obtained empirical results from the previous section are robust and the policy recommendations that we extracted from them are well-grounded. Production process in the agricultural sector can also be affected by factors other than labor and capital. Therefore, other factors, such as agricultural land area, fertilizer, pesticides, rainfall can be potentially considered in the empirical analysis given data availability. We have already included agricultural land area in the empirical analysis above. Additionally, we collected data on fertilizer, pesticides, and rainfall to use them in this robustness check.[22] Particularly, the first two variables can increase agriculture output or productivity. Fig. C.2 illustrates the time profile of the variables over the period under consideration.

The figure portrays that *fepl* and *PESTPL* have an upward trend while *rain* demonstrates a quite stationary pattern over the period. We ran the ADF test on the variables.[23] The ADF test sample value



C.2: Fertilizer, pesticides, and rainfall in Azerbaijan, 1995–2017.
Note: *fepl* is the natural logarithm of fertilizer consumption (kilograms per hectare of arable land) taken from WORLD BANK (2021).
PESTPL is total pesticides use (kilograms per hectare of cropland) retrieved from the FAOSTAT web page, https://www.fao.org/faostat/en/#data/domains_table. As the figure shows, data on *PESTPL* are quite small, ranging in the interval of 0.07 and 0.25. Therefore, we considered the level of the variable not the logarithmic transformation.
rain is the natural logarithm of precipitation, average annual, millimeters downloaded from Climate Change Knowledge Portal for Development Practitioners and Policy Makers (https://climateknowledgeportal.worldbank.org/download-data).

22 We did not consider temperature change. This is because of the following reasons: (i) the data is stationary at its level (see the data at the FAOSTAT web page, https://www.fao.org/faostat/en/#data/domains_table). Therefore, it cannot establish a co-movement with our dependent variable, i.e., agriculture output per labor but we are interested in the the long-run relationship; (ii) we have already three explanatory variables and their one lags in our ADL estimations and will have two more (fertilizer and pesticides) and their one lags additionally but we have only 21 observations. Thus, adding one more and its one lag will further decrease the efficiency of the estimations; (iii) we believe that this indicator is more of climate change related than agricultural activity (even it is under Climate Change section at FAOSTAT web page).

23 In order not to be subject to the omitted variable bias, we included both intercept and time trend in the ADF test equations all three variables. We also included one lag of the dependent variable in each equation and prefer the Schwarz information criterion to select the optimal lag length. It turned out that trend and intercept were statistically significant in the ADF test equations of *fepl* and *PESTPL* while only intercept was significant in the test equation of *rain*. This outcome is quite expected from the visual inspection of the graphical illustration of the variables in Fig. C.2. None of the estimated equations retained the lagged values of the dependent variables indicating that there is not serial correlation issue in the residuals of the equations.

for *fepl* and *PESTPL* are -3.09 and -1.69, respectively. These values are smaller than the respective critical values of from MacKinnon (1996) at any significance level in absolute terms. Hence, we cannot reject the null hypothesis of unit root for these variables. However, the first differences of these variables strongly reject the null hypothesis indicating stationarity. As for *rain*, the ADF test sample value is -3.36, and this is greater than the respective critical value of -3.01 at 5% significance level from MacKinnon (1996) in absolute terms. Therefore, we reject the null hypothesis and accept the alternative hypothesis that *rain* is a stationary process. To conclude the unit root test, we find that *fepl* and *PESTPL* have a unit root while *rain* is a stationary series. Put differently, the first two variables are I(1) processes while the last one is I(0) process.

Selecting Variables in the General Unrestricted Model (GUM)

Next, we extended our cointegration analysis using the ADL modeling by including *fepl* and *PESTPL* there to examine whether they can provide any additional information in explaining *ypl*.[24] To this end, we have *lapl*, *cfpl*, *fepl*, and *PESTPL* as well as one lag of them and *ypl* and intercept. We set the maximum lag orders of the variables at one, and the Schwarz information criterion selects the optimal ones. Tab. C.VI presents the estimated general unrestricted ADL model.

Noticeably, $DBT07_t$ and its lagged value become statistically insignificant now whereas they were statistically significant in the previous ADL estimations discussed in sub-section C.2.2. One can suspect that this is because the pesticides and its lagged value were included in the new general unrestricted ADL specification as the graphical illustration of $PESTPL_t$ in Fig. C.2 portrays almost the same time trajectory as $DBT07_t$. Therefore, we kept current and lagged values of pesticides but excluded dummy variable and its lagged value from the specification with the hope that they will get statistically significant coefficient with expected positive signs. However, both $PESTPL_t$ and its lagged value are highly statistically insignificant. Moreover, they took negative coefficients, as they did before, which is hard to explain given that pesticides could lead to a higher agricultural output. We included time trend in the general unrestricted ADL specification to see whether it helps improve statistical significance of both $PESTPL_t$ and $PESTPL_{t-1}$. However, they are still statistically insignificant with negative signs and time trend is statistically insignificant too. Thus, we decided to replace $PESTPL_t$ and $PESTPL_{t-1}$ with $DBT07_t$ and $DBT07_{t-1}$ to see whether the latter ones are

C.VI: General unrestricted ADL specification.

Panel A: General ADL specification		
Regressor	Coefficient	Std. Error
ypl_{t-1}	0.59*	0.31
$lapl_t$	1.02***	0.18
$lapl_{t-1}$	-0.66*	0.35
$cfpl_t$	0.07*	0.04
$cfpl_{t-1}$	0.01	0.04
$fepl_t$	0.00	0.03
$fepl_{t-1}$	-0.01	0.04
$PESTPL_t$	-0.87	1.22
$PESTPL_{t-1}$	-0.62	0.89
$DBT07_t$	0.14	0.10
$DBT07_{t-1}$	-0.11	0.11
C	0.13	0.41

Panel B: Residual diagnostics and misspecification tests results		
Statistic	Sample Value	Probability
$F_{AR}(1,18)$	0.65	0.44
$F_{ARCH}(1,19)$	0.34	0.56
$\chi^2_N(2)$	4.23	0.12
$F_{Reset}(2,7)$	1.85	0.23

Notes: ypl_t is the dependent variable in the estimations; F_{AR}, F_{ARCH}, F_{Reset} denote F statistics to test the null hypotheses of no autocorrelation, no autoregressive conditioned heteroscedasticity in the residuals and no functional form misspecification, respectively; χ^2_N indicates the Chi-squared statistic to test the null hypotheses of normal distribution of the residuals. *, *** indicates statistical significance at the 10% and 1% levels, respectively. Std. Error means standard errors. Standard error of regression = 0.049. Estimation period: 1997–2017.

statistically significant. We excluded time trend as it was statistically insignificant like it was in the old GUM specification (the one without fertilizers and pesticides in subsection C.2.2). Dummy variable and its lagged value are statistically significant. Their net effect is positive as expected. Most importantly, their inclusion switches the sings of fertilizer and its lagged value from negative to positive, which is what one should expect. Vividly, a GUM with $DBT07_t$ and $DBT07_{t-1}$ seems more relevant than a GUM with $PESTPL_t$ and $PESTPL_{t-1}$. Also, recursive estimation tests results indicate that this GUM does not have any stability issues. Tab. C.VII below reports this specification.

24 We did not include *rain* in the ADL estimations. This is because of almost the first two reasons as we discussed for the temperature variable in footnote 22. Also note that, as a further robustness, we included it in the ADL estimations in addition to *fepl* and *PESTPL*, but the variable did not retain in the selected final conditional specification. Results are available from the authors on request.

C.VII: General unrestricted ADL specification without pesticides

Panel A: General ADL specification		
Regressor	Coefficient	Std. Error
ypl_{t-1}	0.40	0.27
$lapl_t$	0.97***	0.18
$lapl_{t-1}$	-0.54*	0.33
$cfpl_t$	0.06*	0.03
$cfpl_{t-1}$	-0.0004	0.04
$fepl_t$	0.02	0.03
$fepl_{t-1}$	0.02	0.03
$DBT07_t$	0.21**	0.09
$DBT07_{t-1}$	-0.20**	0.09
C	-0.30	0.22

Panel B: Residual diagnostics and misspecification tests results		
Statistic	Sample Value	Probability
$F_{AR}(1,10)$	0.89	0.37
$F_{ARCH}(1,19)$	0.07	0.80
$\chi^2_N(2)$	1.98	0.37
$F_{Reset}(2,9)$	2.54	0.13

Notes: ypl_t is the dependent variable in the estimations; F_{AR}, F_{ARCH}, F_{Reset} denote F statistics to test the null hypotheses of no autocorrelation, no autoregressive conditioned heteroscedasticity in the residuals and no functional form misspecification, respectively; χ^2_N indicates the Chi-squared statistic to test the null hypotheses of normal distribution of the residuals. *, **, *** indicates statistical significance at the 10%, 5% and 1% levels, respectively. Std. Error means standard errors. Standard error of regression = 0.048. Estimation period: 1997–2017.

C.VIII: Final ADL specification from Autometrics

Panel A: Selected final ADL specification		
Regressor	Coefficient	Std. Error
ypl_{t-1}	0.37**	0.15
$lapl_t$	1.02***	0.16
$lapl_{t-1}$	-0.48**	0.20
$cfpl_t$	0.08***	0.03
$DBT07_t$	0.20**	0.08
$DBT07_{t-1}$	-0.17**	0.07
C	-0.23	0.17

Panel B: Residual diagnostics, and misspecification tests results		
Statistic	Sample Value	Probability
$F_{SC}(2,12)$	0.83	0.46
$F_{ARCH}(1,19)$	0.04	0.85
$F_{HETR}(11,9)$	1.68	0.22
$\chi^2_N(2)$	4.23	0.12
$F_{Reset}(2,12)$	1.63	0.24

Notes: *ypl* is the dependent variable in the estimations; F_{SC}, F_{ARCH}, F_{HETR}, F_{FF} and F_W denote F statistics to test the null hypotheses of no autocorrelation, no autoregressive conditioned heteroscedasticity, no heteroscedasticity in the residuals and no functional form misspecification, respectively; χ^2_N indicates the Chi-squared statistic to test the null hypotheses of normal distribution of the residuals. *, **, *** indicates statistical significance at the 10%, 5%, and 1% levels, respectively. Std. Error means standard errors. Standard error of regression = 0.044. Estimation period: 1997–2017.

Selecting Regressors in the Final ADL Specification

We considered the GUM in Tab. C.VII as a congruent GUM since it is statistically well behaved, its regressors take theoretically interpretable signs, and it does not have stability issue. Note that graphical illustration of the fitted values and residuals from this GUM shows that it does not have any considerable outliers. Because of this and given that this GUM successfully passes the post-estimation tests including stability and misspecification as Tab. C.VII reports, we do not need to run *Autometrics* for the impulse indicator saturation to pick up any dummy variable. We applied *Autometrics* to this GUM to select a final specification.[25] The selected final conditional ADL specification is reported in Tab. C.VIII.

The selected ADL specification in the table above successfully passes the residual diagnostics and the misspecification tests. Apparently, the selected conditional final ADL specification in Tab. C.VIII is exactly the same as the one obtained in Tab. C.III.[26]

To conclude this section, we extended our previous GUM with *fepl*, *PESTPL* and their one period lagged values, but none of them survived in the conditional final ADL specification obtained from *Autometrics*. Economically, this means that agriculture output per labor is mainly driven by the market fundamentals, such as capital and land, rather than fertilizers and pesticides in the long run. Statistically, this means that the obtained final ADL specification in Tab. C.III is a robust specification as *fepl*, *PESTPL* and their lagged values do not provide any additional information in explaining the behavior of *ypl*.

25 We selected 5% target size, i.e., statistical significance and unrestricted intercept term to be a part of the long-run relationship as we did previously in sub-section C.2.2.

26 We did not perform the cointegration test and estimate long-run coefficients here as they will be the same as those reported in Panel C of Tab. C.III.

APPENDIX D.

A FURTHER INVESTIGATION OF TFP

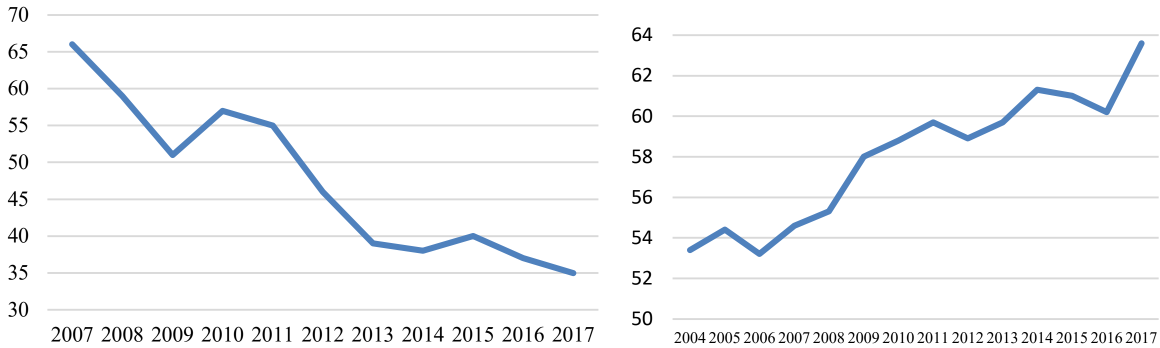
The point is that TFP is nothing else, but the Solow residual and it is calculated as the part of growth, which is not driven by capital, labor and other factors included in a production function (e.g., Solow, 1955, 1957; Acs *et al.*, 2014). In this regard, TFP is considered as a storage for the number of different factors such as increasing returns, labor skills, new ideas, institutions, innovations, technological improvements, efficient use of inputs and other resources, economies of scale, integration among firms, better organization, and management (Acemoglu *et al.*, 2005; Jones and Romer, 2009; Weitzman, 1970; Romer, 1986, 1990; Harberger, 1998; Aghion and Howitt, 1998; Prescott, 1997; Acs *et al.*, 2014). At the same time, TFP as a residual of a regression equation also includes errors and omissions of the data measurements and estimation and hence it has received some critiques, such as not having a meaningful unit of measurement, being subject to the Cambridge Critique (e.g., see Jorgenson and Griliches, 1997; Fuentes and Morales, 2011; Oulton, 2017). Thus, TFP includes both socio-economic factors (we call them signals) and estimation and or calculation errors (we call them noises) and the issue is that it cannot be pinpointed that which portion of TFP are signals and which part of it are noises. Therefore, some economists argue that TFP should be interpreted very carefully while some others even consider it as a model artifact (Sickles and Zelenyuk, 2019; Zelenyuk, 2014). Nonetheless, if an error term from a regression model is the white noise, coefficients are statistically significant and in line with theoretical articulation, then there is a high chance that the signals hold a large portion of TFP. In this regard, our estimation/calculation for TFP should largely contain signals. Note that most of the signals, i.e., socio-economic indicators mentioned above are the building elements of the Global Competitiveness Index (GCI) and Economic Freedom Index (EFI). Definitions and compositions of the indices are briefly documented below here. Fig. D.1 illustrates that Azerbaijan has made significant progress in both indices over time. Briefly note that Azerbaijan has remarkably improved its GCI as the country moved from being the world's 66th competitive economy in 2007 to 35th in 2017. Also, the country made a considerable progress in EFI as the score grew from 53.4 in 2004 to 63.6 in 2017. The developments in both indices would not be possible without an improvement in their compositions, i.e., above mentioned socio-economic indicators as well as in the institutions.

To achieve these developments in the agriculture sector, among other things, the government takes measures, highlighted in Strategic Roadmap on production and processing of agricultural products in the Republic of Azerbaijan adopted in 2016, such as to increase efficiency of state regulation in the sector; to develop the system of science, education and services; to support the establishment of new agricultural parks; to enhance the market infrastructure and business environment for agricultural products and facilitate the access of the producers to the markets. It also implements technical assistance and grant projects jointly with the European Union, Turkey, Japan, and several other countries.

Considering that these indicators are also the main compositions of TFP, it can be concluded that TFP increases especially since 2004 illustrated in Fig. 3 have been mostly driven by the signals than noises. Therefore, the positive contributions of the TFP to the agriculture growth in Fig. 3 can be regarded as enhancements of the above-listed signals, such as technological improvement, efficiency gain, and better management in the sector.

Definition of the Global Competitiveness Index (GCI)

The World Bank defines GCI as follows: "The GCI analyses competitiveness along 12 pillars: institutions, infrastructure, macroeconomic environment, health and primary education, higher education and training, goods market efficiency,



GCI rank *EFI score*

D.1: GCI and EFI for Azerbaijan

labour market efficiency, financial market development, technological readiness, market size, business sophistication and innovation." (https://tcdata360.worldbank.org/indicators/gci?country=AZE&indicator=632&countries=BRA&viz=line_chart&years=2007,2017).

Definition of the of Economic Freedom Index (EFI)

Heritage Index of Economic Freedom webpage defines the index as below (https://www.heritage.org/index/about): "The Index of Economic Freedom has provided powerful evidence that economic freedom, measured in the Index by factors related to the rule of law, limited government, regulatory efficiency, and open markets, is the answer to that simple yet profoundly consequential question. We measure economic freedom based on 12 quantitative and qualitative factors, grouped into four broad categories, or pillars, of economic freedom: (i) Rule of Law (property rights, government integrity, and judicial effectiveness); (ii) Government Size (government spending, tax burden, fiscal health); (iii) Regulatory Efficiency (business freedom, labor freedom, monetary freedom); (iv) Open Markets (trade freedom, investment freedom, and financial freedom). Each of the twelve economic freedoms within these categories is graded on a scale of 0 to 100. A country's overall score is derived by averaging these twelve economic freedoms, with equal weight being given to each.