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EFFECTS OF INNOVATION ADVANCEMENT ON ECONOMIC GROWTH IN UGANDA: A GENERALIZED LEAST SQUARES APPROACH

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Abstract: *The paper uses the generalized least squares method to examine the effects of innovation advancement on economic growth in Uganda during the 1970 to 2020 period. Data sets employed in conducting empirical analyses were collected from the United Nations database. The paper is based on the neoclassical growth model with decreasing returns to scale because production often takes place within the feasible region of production. We also examine the effects of innovation on capital, labor, capital productivity, labor productivity, household consumption, investment spending, government spending, exports, imports, etc. in Uganda during the given period. Furthermore, we examine the influence of other variables on innovation and the individual influence of innovation on those variables. Empirical results show that innovation advancement caused economic growth and growth of other microeconomic variables in Uganda during the given period. All the variables considered had significant feedback effects on innovation. Hence, we recommend the application of innovation advancement to a great extent to enhance Uganda's economic growth; since it had most long term effect on economic growth in Uganda during the given period.*

Keywords: Keywords: Economic growth, Innovation advancement, technological progress, capital productivity growth. Investment growth

1. Introduction

Our major objective is to examine effects of innovation on economic growth in Uganda during the 1970 to 2020 period using the generalized least squares (GLS) method. In our paper, innovation is derived from the neoclassical model and defined as the ratio of the total product (output) to output raised to the sum of capital and labour output elasticities. In both macroeconomics and microeconomics, the paper marks the beginning of expressing or estimating innovation in terms of levels of technology, capital productivity, labour productivity, and output elasticities of capital and labour. Meanwhile, the level of technology is defined as the ratio of output to total factor productivity. On the other hand, we define the technology index as the ratio of the logarithm of technology to the logarithm of output. In contrast, the innovation index is defined as the ratio of the logarithm of innovation to the logarithm of output.

However, in most existing quantitative research, innovation has been measured in terms of the total number of patents, trademarks, and Research and Development (R&D) expenditures. Meanwhile, recent economic growth theories postulate that innovative products, processes, and business models as outcomes of continuous research and innovation are the key drivers of productivity and economic growth. These hypotheses have not been empirically tested in the case of Uganda, especially at a macroeconomic level. One of our models shows that components of output that can directly influence innovation are household consumption, investment spending, government spending, exports, and imports. The neoclassical model demonstrates that innovation advancement depends on technological progress and capital and labour productivity growth.

Moreover, according to Ecuru (2011, p.20), innovation involves interactive learning and effects between firms, other organizations, and all economic agents in a particular setting. In Uganda, these interactions and how they affect innovation advancement are less understood. As a result, there is often disagreement among policy makers and other actors on actions required to support the innovation process in the country. However, the paper focuses on the transmission mechanism (pass-through) of the effects of growth in exogenous factors on economic growth that occurs through innovation advancement. Empirical findings show that a 1 per cent increase in innovation growth could have caused economic growth to rise by 3.55 per cent yearly in Uganda during the given period.

Similarly, a 1 per cent increase in innovation growth could have caused the growth of some other microeconomic variables to indibidually rise by approximately 3.55 per cent yearly in the country during the given period. Meanwhile. during the 1974-2020 period, a 1 per cent increase in growth of consumption, investment, government spending, exports, and imports could have caused annual innovation advancement to rise by 0.252, 0.035, 0.021, 0.021, and -0.048 per cent, respectively, during the given period. This result indicates that very high contribution of innovation to output in Uganda during the given period.

Moreover, some of the macroeconomic variables that innovation advancement affected had approximately the same level of effects as it had on economic growth, namely: technology, capital, capital productivity, labour, labour productivity, income per capita, population size (level of technology diffusion), household consumption, investment spending, government spending, exports, imports, disposable income, economic profits, and total cost of production. All the variables considered were found to have had significant feedback effects on innovation advancement during the given period. In the paper our major contribution is the introduc of the innovation variable just as the technology variable was introduced into the Cobb-Douglas production function by Solow (1956). Therefore, just as output is a function of technology, capital and labor; technology is a function of innovation and productivity of inputs.

2. Review of Literature

2.1. Concept of Innovation

Schumpeter (1934) defines innovation as “the setting up of a new production function.” This definition includes new commodities, a new form of organization (e.g., a merger), and the opening up of new markets. Meanwhile, Edquist, Hommen, and McKelvey (2001) view innovation as “new commodities,” new technologies or product innovations within “the setting up of a new production function,” and new organizational and technological processes that have evolved to lead further into innovation.

In addition, Schumpeter (1934) views innovation as a new use or a “new combination” of existing factors. That is, using existing technologies, knowledge, or new ways that have not been applied before. Nelson and Winter (1993) support this view by arguing that invention is often successfully commercialized by someone other than the inventor. For innovation to be successful, it may take a long time after the invention has occurred. A new product or process to be characterized as innovation requires successful diffusion.

Innovation is doing new things differently or things that have already been done in a new way. As a concept, innovation can be defined in five ways: (a) the introduction of a new product, (b) a qualitative change in an existing product (incremental innovation), (c) the implementation of a new production or transportation method new to an industry or the opening of a new market, (d) development of new sources for raw materials, and inputs and (e) changes in the industrial organization, i.e., monopolization of industry (Peters, 2008; Freeman and Soete, 1997; Fagerberg and Verspagen, 2009; Dosi,1988).

Innovation is a necessary change or novelty. Such a change is understood as incremental, new production or introduction of outputs. Chen, Zhu, and Xie (2004) define innovation as introducing new or combinations of the essential factors of production into the production system, where the factors of production include human capital in R&D activities. They also define R&D activities as indicators of innovation and identify the sophistication level of innovation production factors, the type of innovation determinants to be used, and the mechanisms under which these factors can be applied in different contexts that are integral to understanding the mechanics of innovation.

Innovation can be interpreted in a multitude of ways. It can be viewed as (a) the competence of organizing and implementing research and development or (b) bringing forth new technology and product to meet the demands of customers (Plessis, 2007). Innovation refers to a: new product, new technology, new market, new material, or new combination. Many researchers view innovation as the amount allocated for R&D and the number of patent rights granted or applied annually. As a process, innovation involves knowing how much the available innovation activities are being implemented. Thus, innovation involves providing new mechanisms for new approaches, inputs, and outputs.

Furthermore, as a process, innovation encompasses technical and physical activities central to forming product innovations and development routines (Cardinal, Alessandri, and Turner, 2001). To some researchers, innovation is viewed as a process of knowledge accumulation. They argue that a society with a good stock of knowledge can innovate better than a society with less human capital (knowledge). Therefore, today's economically and technologically developed countries can better engage in knowledge production and application than the underdeveloped world. Oslo Manual is the authoritative and standard definition of innovation (OECD, 2005). It defines innovation as implementing a new or significantly improved product (good or service) or process, a new marketing, or a new organizational method in business practice, workplace organization, or external relations.

The minimum requirement for innovation may be the product, process, marketing method, or organizational method that must be new or significantly new to a firm or market. The manual names four types of innovation: product, process, marketing, and organizational innovations. Product and process innovations are the most popular. They are closely related to the concept of technological product and process innovation. However, marketing and organizational innovations are not popular or recognized due to measurement problems (Tiruneh, 2014, pp.44-47).

2.2. Innovation Theory

Enhancing technological knowledge has been recognized as the most critical factor for enhancing long-term effects on productivity and economic growth (Grubler et al., 1999). As a result, the innovation process and the specification of actions needed to generate technological progress continue to be of central interest to businesses, governments, and academics. Furthermore, innovation is increasingly recognized as important for controlling the negative side effects of productivity and economic growth. Therefore, controlling the direction of innovation towards more sustainable directions is highly important (Hekkert and Negro, 2009).

Innovation is a catch-all term (Slade and Bauen, 2009). It differs from invention (defined by Schumpeter (1939) as the first discovery of new products or processes). Innovation may be used interchangeably with technological change to describe the steps required to get a new product to market. Sometimes, innovation refers to a new product itself, a stage in a product's lifecycle, or an iterative process of invention and application that links technical, societal, and political change. Innovation may be classified as incremental, radical, or disruptive depending upon whether it originates within or outside the mainstream and whether it renders an incumbent technology (or process) obsolete. Innovation theory does not refer to a single discipline or school of thought (Gross, 2010).

Instead, innovation represents conceptual strands drawn from various academic disciplines and research areas, including the economics of increasing returns, behavioural economics, and business school, i.e., competitive advantage, analysis of national systems, and socio-technical regimes. There are different and various theories of innovation. Thus, there is a shared understanding that the technologies themselves typically undergo several stages of commercial maturity, starting with basic and applied R&D. Innovation involves demonstration stages such as (a) prototypes, financed mainly through R&D grants; (b) reasonably broad pre-commercial stage of development where multiple units of previously demonstration-stage technologies are installed for the first time, (c) the first few multiples of units move too much larger scale installation for the first time; and (d) a supported commercial stage with given support measures and technologies are rolled out in substantial numbers. When successful results in the final commercial stage of technology compete, unsupported within the broad regulatory framework (Foxon et al., 2005). However, the above stages are no longer interpreted as a one-way linear flow. In the innovation theory that has been developed, it has been that knowledge flows are in both directions.

For instance, information from early market applications feeds back into further research. This approach means that the conventional drivers of technology-push from R&D, and market-pull from customer demand, can be reinforced or inhibited by the (a) feedback between different stages and (b) influence of framework conditions, e.g., government policy and risk due to lack of capital. Consequently, contemporary innovation theorists do not simply frame the barriers to innovation in terms of a market failure whereby innovation is relatively expensive compared to incumbent alternatives that struggle to be adopted by consumers.

That is because the benefits are societal (e.g., environmental) rather than private. Instead, framing the problem can be expanded to include the concept of a broader systems failure in the innovation arena as a whole. Such a system may include failures in infrastructure provision, transition and lock-in failures, and institutional and regime failures (OECD, 2002; Greenacre et al., 2012).

2.3. Innovation as an Exogenous and Endogenous Theory

The classical theories, like those of Adam Smith and Karl Marx, show technological change and economic development as an essential part. However, from the late nineteenth century to the early twentieth century, neoclassical theorists ignored technological change and economic development, while neoclassical theories dominated the era (Verspagen, 2005). It was only after 1945 that interest in development theories started to flourish (Brue, 2013). Innovation was neglected or omitted in some of these economic growth theories. Although some development theories were composed of innovation, they treated it as an exogenous factor. Neoclassical economics focuses on the optimal allocation of resources and the adaptations following exogenous shocks such as demographic change, changing preferences, etc. (Hanusch and Pyka, 2007). Therefore, Schumpeter's view of innovation is internal to the economy instead, and it is repressible for driving internally the economy personified by the audacious entrepreneur (Omer, 2018).

Solow (1956), as a mainstream economist, considers innovation as an exogenous factor and treats technological change as an exogenous factor. For him, growth cannot be explained by the variables endogenous to the model but results from exogenous technical change (Fagerberg et al., 2005). According to Solow's (1956) growth model, endogenous variables in the model are capital and labour, while technological change is treated as an exogenous variable in the production function. Brue (2000) finds that increases in labour and capital inputs explain less than half of economic growth, and the rest comes from technological progress.

Solow (1956) states that sustained economic growth is attributed to technological progress. Therefore, without technological progress, per capita growth eventually ceases as diminishing returns to capital sets in. Meanwhile, technological progress can outweigh the potential for the marginal product of capital to fall. As a result, in the long run, countries exhibit a per capita growth rate of technological progress. Solow (2008) highlights the importance of technological change in economic growth. His theory sharply contrasts with that of Schumpeter.

Romer (1986) was the first introduced to treat innovation as an endogenous variable and develop a model to incorporate technological change as an endogenous factor. His model incorporates technological change as an endogenous factor in economic growth theories. However, his model retains another equilibrium model similar to the neoclassical growth models (Eggink, 2011). Schumpeter (1939) advances a development theory with innovation as the major driving force, endogenous to the economy and disturbing to the equilibrium. He is little concerned with the effect of exogenous shocks on the economy. He focuses on the endogenous effect of innovation on the development process (Hanusch & Pyka, 2007). Thus, innovation is internal to the economy and an irrepressible internal driving force in the economy personified by the audacious entrepreneur. Schumpeter (1939) sees the economy as evolutionary and argues that capitalism is a form or method of economic change by its very nature. It never is and never can be stationary.

Schumpeter (1939) views the evolutionary character of the capitalist process as a consequence of productive change. According to him, innovation persistently revolutionizes the economic structure from within while destroying the old one and creating a new one.

This process of creative destruction is the essential nature of the capitalist" (Schumpeter, 1976). The description of creative destruction powerfully describes what Schumpeter (1939) believes in. He contends that innovation provides energy to the economy and makes economic growth possible. However, some aspect of the growth of monopolistic corporation ultimately erodes the environment for innovation and undermines capitalism. Thus, his memorable description and conception of creative destruction resonate today.

Schumpeter (1939) argues that the continuous innovation process comprises two stages: a discrete rush of innovation and a period of absorption of the results of that innovation, where the process existing in these stages together form a business cycle. According to Hanusch and Pyka (2007), economic development has to be considered a process generated within the economic system that endogenously destroys every equilibrium that might be reachable. Schumpeter (1939) refers to this energy source as a catalyzing function, thus disturbing the equilibrium and generating development. Schumpeter (1939) describes innovation as an internal factor of change.

According to Schumpeter (1939), innovation is an internal factor because the channeling of the existing factors of production to new uses is purely an economic process, while in a capitalist society, it is purely a matter of business behaviour. The endogenous nature of innovation differs from that of neoclassical economists regarding the production function. Innovation does not vary the quantities of the factors of production in order to produce different quantities, as described by neoclassicism. Therefore, innovation causes an entirely new production function (Schumpeter, 1939). Hence, this new production function can represent the production of a new product. Otherwise, the new production function can represent the change of the inputs or method of production of an existing product.

2.4. Contribution to the Effects of Innovation on Economic Growth

For many decades economists have been interested in the role of innovation in economic growth and development. In the neoclassical framework, innovation is treated as total factor productivity (TFP) or part of the Solow residual.

Hence, innovation contributes to economic progress and long-term convergence (Solow 1957; Fagerberg 1994). Meanwhile, in recent decades endogenous growth theories have become more popular than exogenous growth theories. Therefore, economists are increasingly considering differences in innovation capacity and its potential as being primarily responsible for persistent variations in economic performance and hence the wealth of nations in the world (Grossman & Helpman, 1991; Wu, 2009). Some countries grow continuously for many years, but others stagnate. Meanwhile, some countries grow faster than others. The theoretical breakthrough in explaining these differences that Solow (1956) and Romer (1990) started has lost momentum, leaving some important questions unsettled. In both neoclassical and endogenous growth theories, technological advance is believed to be the major driver of economic growth.

However, how new knowledge translates into superior economic performance by countries has neither been described by the growth theories nor found to have an unequivocal empirical explanation. Empirical studies that lack theoretical underpinnings focus on networks (Wal and Boschma, 2009), labour mobility (Almeida and Kogut, 1999), and other potential facilitators of spillovers (Tsvetkova, 2015; Maradana et al., 2017). The existing literature shows that many studies have investigated the contribution of total factor productivity (TFP) changes to economic growth. In those studies, innovation is treated as part of the TFP contribution to economic growth, not explained by changes in factor inputs (Wu, 2009).

In our study, the gross expenditure on research and development (GERD) as a per cent of gross domestic product GDP is extended to the current literature by measuring innovation using an alternative approach. Thus, we measure innovation (Z) as the ratio of GDP to GDP raised to power $\alpha + \beta$, where α, β are the coefficients of capital and labour, respectively. Therefore, innovation can be defined mathematically as follows: $Z = Y/(Y^{\alpha+\beta}) = Y^{1-\alpha-\beta} = A/(K_p^{\alpha}.L_p^{\beta})$, where K_p is capital productivity and L_p is labour productivity. In the last two decades, both researchers and policymakers have increasingly investigated the relationship between innovation, entrepreneurship, and regional outcomes (Galindo and Mendez-Picazo, 2014; Grossman, 2009; Howells, 2005; Malerba and Brusoni, 2007; Tsvetkova, 2015; Wang et al., 2005).

However, in this present study, we specifically examine the relationship between innovation and economic growth in Uganda. More specifically, since the seminal work of Schumpeter (1911), innovation has been considered one of the key drivers of economic growth (Andergassen et al., 2009; Bae and Yoo, 2015; Mansfield, 1972; Nadiri, 1993; Romer, 1986; Santacreu, 2015; Solow, 1956; Mardana et al., 2017). Innovation affects the economy through many channels, e.g., economic growth, global competitiveness, financial systems, quality of life, infrastructure development, and employment, and generates high economic growth (Hassan and Tucci, 2010). Most of the innovation studies focus on the effect of innovation on economic growth, and they deal with the supply-driven approach to innovation-growth.

However, economic growth indeed increases the level of innovation in the development process. Therefore, it is possible to have a bidirectional causality between innovation and economic growth (Pradhan et al., 2016; Mardana et al., 2017). Hence, the main objective of this paper is to examine the bidirectional linkage between innovation and economic growth. Consequently, this paper uses the generalized least squares approach to examine the dynamics between innovation and economic growth in Uganda during the 1970 to 2020 period. The study's main contribution is to examine the effects of innovation on economic growth by finding out the influence of innovation activities on economic growth and the effects of rapid economic growth on innovation advancement.

3. Theoretical Framework

In our theoretical framework, we take growth in output (Y) to be a function of growth in the level of innovation (Z) while α, β are returns to scale on capital and labour, respectively.

$$\frac{d(Y)}{Y} = \frac{1}{1-\alpha-\beta}\frac{d(Z)}{Z}. \quad (3.1)$$

Rearranging Equation (3.1) implies that the marginal product of innovation depends on the average product of innovation and can be expressed as follows:

$$\frac{d(Y)}{d(Z)} = \frac{1}{1-\alpha-\beta}\frac{Y}{Z}. \quad (3.2)$$

Here we treat the behaviour among the variables to be interactive such that the expression is capable of representing the influence of output on innovation:

$$\frac{d(Z)}{Z} = (1-\alpha-\beta)\frac{d(Y)}{Y}. \quad (3.3)$$

Therefore, innovation can be expressed as a function of consumption, investment spending, government spending, exports, and imports, then represented by

$$Z = \left(C_n^{\beta_1} I^{\beta_2} G^{\beta_3} X^{\beta_4} I^{\beta_5}\right)^{1-\alpha-\beta} = Y^{1-\alpha-\beta}. \quad (3.4)$$

where the parameters $\beta_1, \beta_2, \beta_3$ & β_4 are all positive but β_5 is negative.

Meanwhile, the level of technology (A) can be represented as a function of quantities of innovation, capital productivity(K_p) and labour productivity (L_p) and written as follows:

$$A = Z^{\frac{1}{1-\alpha-\beta}} K_p^{\alpha} L_p^{\beta}. \quad (3.5)$$

Likewise, the level of technology can be represented as a function of quantities of innovation, capital, and labour, then written as follows:

$$A = ZK^{\alpha}L^{\beta}. \quad (3.6)$$

On the other hand, the level of output can be represented as a function of levels of innovation, capital productivity, and labour productivity, then written as follows:

$$Y = Z^{\frac{1}{1-\alpha-\beta}} K_p^{\alpha} L_p^{\beta}. \quad (3.7)$$

Meanwhile, the quantity of capital can be represented as a function of both innovation and capital productivity and expressed simply as follows:

$$K = Z^{\frac{1}{1-\alpha-\beta}} K_p^{-1}. \quad (3.8)$$

where output is the product of capital and capital productivity, $Y = KK_p$. Thus, this implies that the level of capital productivity can be represented as a function of quantities of both innovation and capital and expressed just as follows:

$$K_p = Z^{\frac{1}{1-\alpha-\beta}} K^{-1}. \quad (3.9)$$

where output is the product of capital and capital productivity, $Y = KK_p$.

Similarly, the level of labour productivity can be represented as a function of quantities of both innovation and labour and expressed just as follows:

$$L_p = Z^{\frac{1}{1-\alpha-\beta}} L^{-1}. \quad (3.10)$$

where output is the product of labour and labour productivity, $Y = KK_p$. Thus, implying that the quantity of labour can be represented as a function of both innovation and labour productivity and expressed simply as follows:

$$L = Z^{\frac{1}{1-\alpha-\beta}} L_p^{-1}. \tag{3.11}$$

where output is the product of labour and labour productivity, $Y = KK_p$.

Furthermore, we present the mathematical expression for the effects of innovation and population P_0 (i.e., level of technology diffusion) on per capita income Y_p as given by

$$Y_p = Z^{\frac{1}{1-\alpha-\beta}} P_o^{-1}. \tag{3.12}$$

Similarly, the mathematical representation of the effects of innovation and income per capita (Y_p) on population size (P_o) is portrayed by Equation (3.13).

$$P_o = Z^{\frac{1}{1-\alpha-\beta}} Y_p^{-1}. \tag{3.13}$$

Meanwhile, we represent the level of technology as a function of levels of both innovation and total factor, as shown in Equation (3.14).

$$A = Z^{\frac{1}{1-\alpha-\beta}} T_F^{-1}. \tag{3.14}$$

On the other hand, we represent the level of total productivity as a function of levels of both innovation and technology, as shown in Equation (3.15).

$$T_F = Z^{\frac{1}{1-\alpha-\beta}} A^{-1}. \tag{3.15}$$

Since $Y \equiv Z^{1/(1-\alpha-\beta)} \equiv Y_d + T \equiv W + TC \equiv C_n + I + G + X - M$, from Equations (3.16) to (3.16). Thus, in each of the partial derivative equations with two variables; each of the dependent variables can be represented as follows: $Q = C_n, I, G, X, M, Y_d, W, TC.$ follows:

$$\partial(\mathrm{Q}) = \frac{1}{1-\alpha-\beta} \partial \log (Z). \tag{3.16}$$

where Y is GDP, Z is innovation, C_n is consumption, I is an investment, G is government spending, X is export, M is import, Y_d is disposable income, T is tax revenue, W economic profit, TC total cost and α, β are parameters of returns to scale on K and L, respectively.

Thus, we present the relationship between innovation and technology to be interactive such that levels of innovation and technology affect each other. In particular level of innovation is represented as a function of levels of technology, capital and labour, then written as follows:

$$Z = \left(AK^{\alpha}L^{\beta}\right)^{1-\alpha-\beta}. \tag{3.17}$$

Similarly, we present the relationship between innovation and technology to be interactive such that the level of innovation and technology affect each other. In particular level of innovation is represented as a function of levels of technology, capital productivity and labour productivity, and written as given in Equation (3.25).

$$Z = \left(AK_p^{-\alpha}L_p^{-\beta}\right)^{\frac{1}{1-\alpha-\beta}}. \quad (3.18)$$

Nevertheless, we present the usual neoclassical equation to depict the effects of technology level, quantities of both capital and labour on economic growth.

$$Y = AK^{\alpha}L^{\beta}. \quad (3.19)$$

Meanwhile, we present the theory that growth in innovation productivity $d(\log(Y/Z)$ depends on the level of technological advancement and depict the represented as follows:

$$d(\log(Y/Z) = \alpha_1 d(\log(A)). \quad (3.20)$$

The rate of technology diffusion or innovation diffusion could be measured by the rate r at which technology diffuses within a given population ($P_o = 10^r Y_p^q$) of a country with income per capita (Y_p) and income per capita elasticity on population (s), as follows:

$$\log(P_o) = r\log(10) + s\log(Y_p). \quad (3.21)$$

Consequently, we compute the annul innovation indices as follows:

$$I_{Zt} = [\ln(Z_t)/\ln(Y_t)] = 1 - \ln(I_t/Y_t) - ln(C_{nt}/Y_t). \quad (3.22)$$

where output equals technology raised to an index: $Z_t = {Y_t}^{I_{Zt}} = Y_t^{1-\alpha_t-\beta_t}$.

Last we suggest, (a) computation of the annul technology indices as follows:

$$I_{At} = 1 - [\log(T_{Ft})/\log(Y_t)]. \quad (3.23)$$

where output equals technology raised to an index: $Y_t = A^{I_{At}}$.

(b) compute the annul technology innovation indices as follows:

$$I_{AZt} = [\log(A_t)/\log(Y_t)]. \quad (3.24)$$

where output equals technology raised to an index: $Y_t = A^{I_{AZt}}$

(c) compute the simple annul innovation indices as follows:

$$I_{SZt} = [\log(Z_t)/\log(Y_{dt})]. \quad (3.25)$$

where output equals technology raised to an index: $Y_t = A^{I_{SZt}}$.

4. Methodology

4.1. Data Types and Data Sources

The dataset employed in the study was composed of secondary data collected from the United Nations (2020) database. The time series dataset collected contained household consumption, investment spending, government spending, exports, imports, and population of Uganda covering 1970 to 2020. Data got from the dataset were: capital, labour, capital productivity, labour productivity, disposable income, economic profit, level of technology, innovation, total factor, technology index, innovation index, innovation productivity, and capital productivity.

4.2. Data Generation Process

4.2.1. Deriving a Formula for the Generation of Quantity of Capital Stock

Given that the gross investment spending is (I_t) denoted by, and the rate of depreciation of Capital stock is denoted by (δ_t). Then capital stock (K_t) can be represented in the form of the capital accumulation equation as follows:

$$K_t = K_{t-1} - \delta_t K_t + I_t. \quad (4.1)$$

Similarly, given that the flow of total physical depreciation of capital (D_t), then the capital stock movement is provided in Equation (4.2). Therefore, for each year, the annual amount of depreciation can be expressed as follows (Hulten & Wykoff, 1981):

$$K_t = K_{t-1} - D_t + I_t. \quad (4.2)$$

Subtraction of Equation (4.2) from Equation (4.1) and simplifying the result gives

$$K_{t-1} = \frac{D_t}{\delta_t}. \quad (4.3)$$

While at equilibrium, a change in capital stock equals the change in investment spending, and their dynamics can be rewritten as follows:

$$K_t - K_{t-1} = I_t - I_{t-1}. \quad (4.4)$$

Adding Equations (4.1) and (4.4) shows that $D_t = I_{t-1}$. Therefore, Equation (4.3) becomes

$$K_{t-1} = \frac{I_t}{\delta_t}. \quad (4.5)$$

From Equation (4.5), it can be deduced that for every year, Equation (4.6) holds

$$dI_{t-1} = \delta_t . dK_{t-1}. \quad (4.6)$$

∴ $$I = \delta_t . dI_{t-1}. \quad (4.7)$$

∴ $$1 = \delta_t . \frac{dI_{t-1}}{I_t}. \quad (4.8)$$

∴ $$\delta_t = \frac{1}{\log(I_{t-1})}. \quad (4.9)$$

Hence, after substituting Equation (4.9) in Equation (4.5), we obtain an expression that can generate the quantity of capital stock provided the quantity of investment is known.

$$K_{t-1} = I_{t-1}\log(I_{t-1}). \quad (4.10)$$

Otherwise $$K_t = I_t \log(I_t). \quad (4.11)$$

4.2.1. Data Generation of Levels of Technology and Innovation and Quantity of Labour

This study extends the current method of computing the level of innovation by defining it not as the residual of the level of technology but presenting it as a function of capital and labour productivity. To define TFP, the Cobb-Douglas version of the production function in use is given by output (Y) as a function of technology (A), capital (K), labour (L) and parameters α, β (Lipsey & Carlaw, 2004). $$Y = AK^{\alpha}L^{\beta}. \quad (4.12)$$

where $$0 < \alpha + \beta < 1.$$

The TFP is calculated by dividing through Equation (4.12) by the total factor $K^{\alpha}L^{\beta}$ to provide

$$TFP = \frac{Y}{K^{\alpha}L^{\beta}} = A. \quad (4.13)$$

Similarly, to define innovation (Z), the Cobb-Douglas version of technology function in use is represented by the level of technology (A) as the function of innovation (Z), capital productivity (K_p), labour productivity (L_p) and parameters α, β.

$$A = ZK_p{}^{\alpha}L_p{}^{\beta}. \quad (4.14)$$

∴ $$Z = Y^{1-\alpha-\beta} = AK_p{}^{-\alpha}L_p{}^{-\beta}. \quad (4.15)$$

In other words, the level of technology is given by $A = ZK_p{}^{\alpha}L_p{}^{\beta}$. Having obtained the time series data on the annual long run capital stock (K_{t-1}) and aggregate disposable income (Y_{dt}), the annual quantities of labour (L_{t-1}) can be generated by using the classical Cobb-Douglas production function $[Y_{dt} = K_{t-1}^{\alpha} L_{t-1}^{\beta}]$ and by causality theory (Mishkin, 2004, p. 116), where α is average propensity to invest (MPI_t) and β is average propensity to consume (APC_t). From the Cobb-Douglas, we make L_{t-1} the subject and obtain

$$L_{t-1} = \left[Y_{dt}/\left((K_{t-1})^{(API_t)}\right)\right]^{[1/APC_t]}. \quad (4.16)$$

since the long run MPC_t equals long-run APC_t. Implying a marginal propensity to invest (MPI_t) and average propensity to invest (API_t) are equal in the long run (Hadden, 1965, p.9).

4.3. The Generalized Least Squares (GLS) Method

The proposed GLS model can be represented as follows:

$$y = X\beta + u \qquad u \sim N(0, \sigma^2\Sigma) \quad (4.17)$$

where Σ is a positive definite matrix of order n. This model suffers from variances that are not constant; instead of the constant variance, $var(u) = \sigma^2 I$. If the proposed GLS model was a sample model, then pre multiplying Equation (4.17) by X' provides a GLS equation that could be represented as

$$X'y = X'X\beta \quad (4.18)$$

since $X'u = 0$. Manipulation of Equation (4.3.2) provides an expression for β.

$$\beta = (X'X)^{-1}X'y \quad (4.19)$$

Given that $\boldsymbol{\Sigma}$ is a positive definite, then its inverse is a positive definite as well. As a result, it is possible to find a nonsingular matrix such that

$$\Sigma^{-1} = P'P. \quad (4.20)$$

In order to get rid of autocorrelation and heteroskedasticity, each vector and matrix in Equation (4.19) can be transformed by pre-multiplying the given vector and matrix by vector, P.

$$\beta_{GLS} = [(PX)'(PX)]^{-1}(PX)'(Py). \quad (4.21)$$

$$\therefore \quad \beta_{GLS} = (X'P'PX)^{-1}X'P'PXy \quad (4.22)$$

$$\therefore \quad \beta_{GLS} = (X'\Sigma^{-1}X)^{-1}X'\Sigma^{-1}Xy \quad (4.23)$$

The vector of estimated coefficients provided here would be precise as those obtained from the OLS regression of the vector Py and matrix PX. Pre-multiplying the linear model in Equation (4.17) by a nonsingular matrix satisfies Equation (4.20). Thus, leading to the following

$$y_* = X_*\beta + u_* \quad (4.24)$$

The expression $\Sigma = P^{-1}(P')^{-1}$ is derived from Equation (4.20). It then follows from Equation (4.24) that $Var(u_*) = E(Puu'P') = \sigma^2 P\Sigma P' = \sigma^2 PP^{-1}(P')^{-1}P' = \sigma^2 I.$ (4.23)
Therefore, the OLS theory provides an implication that

$$Var(\beta_{GLS}) = \sigma^2(X_*'X_*)^{-1} = \sigma^2(X'\Sigma X)^{-1}. \quad (4.26)$$

(Johnston and Dinardo, 1997, pp.151-153).

4.5. Econometric/Statistical Tests

Using the generalized least squares (GLS) method, we perform linear regression analyses on secondary data collected from the United Nations Data Base on Uganda covering 1970 to 2020. Data used in empirical analyses are on aggregate household consumption and investment spending, government spending, exports and imports because they are the variables commonly present in the household consumption function, national income model and neoclassical function. Data generated were as follows: gross domestic product (GDP), household disposable income, capital productivity, labour productivity and total factor.

Innovation, technology, innovation index, and income taxes. The t, F, DW and H_T statistical tests were conducted by comparing the computed t, F, DW and H_T values with their respective critical values from the standard Statistical Tables. The H_T is the computed t value used in testing for heteroscedasticity (variances that are not constant) by conducting the usual t tests.

5. Presentation and Discussion of Results

From Equation (5.1) it is clear that a 1 per cent increase in innovation advancement could have caused yearly economic growth to rise by 3.55 per cent during the 1974 to 2020 period in Uganda. This spectacular influence of innovation on economic growth in Uganda is supported by overwhelming literature regarding the influence of innovation on economic growth. For instance, innovation has been widely accepted as the most effective driving force for industrial catch-up, endogenous economic growth, sustainable competitive advantages, and enhancing global sustainable growth (Dosi, 1982; Fu and Gong, 2011; Lee, 2016; Lewin et al., 2016; Lee and Malerba, 2017; Mazzucato, 2018; Chen, et al., 2020a; Chen et al, 2021).

$$d(Y)/Y = 3.55d(Z)/Z. \quad (5.1)$$

t 1169529

$R^2 = 1.00$ $DW = 2.01$ Period: 1974-2020

$N = 47$ $HSDT = 0.00$ $Vector = 1/(d(d((d(TF_{-1}))^2))$

Equations (5.1) and (5.2) indicate that the effect of average product of innovation on marginal product of innovation is equal to the effect of growth in innovation on economic growth. Thus, a 1 percent increase in innovation productivity growth during the 1975 to 2020 period could have been the driving force behind the 3.55 percent rise in the yearly marginal productivity growth in Uganda. Therefore, innovation causes output at an increasing rate and the production process involving application of innovation involves increasing rate of return.

$$d(Y)/d(Z) = 3.55d(Y/Z). \quad (5.2)$$

t 3594143

$R^2 = 1.00$ $DW = 2.05$ Period: 1975-2020

$N = 45$ $HSDT = 0.00$ $Vector = 1/(d(d((d(TF_{-1}))^2))$

Expenditures on R&D are considered as intermediate inputs for businesses and current consumption for nonprofit institutions and general government. The, available R&D resources are used to create products or output for future, rather than current, consumption. Usually. it provides output and benefits starching long into the future, mainly for 17 years, or more recently 20 years of patent protections. Therefore, R&D is more of an investment than intermediate inputs or current consumption. Research and development (R&D) efforts made by individuals, firms, and governments usually affect technical progress and innovation attributes. The relationship among R&D, technical progress, and economic growth is widely known. But this relationship is difficult to quantify because the R&D produce gains and output as critical components of the relationship, that are hard to measure. (Fraumeni & Okubo, 2002).

According to our estimate in Equation (5.3), a 1 per cent increase in GDP could have been responsible for 0.28 per cent rise in annual innovation growth in Uganda during the 1973 to 2020 period ceteris paribus. Therefore, we find that the output elasticity of innovation during the given period was 0.28 percent. Meanwhile, apart from Uganda, Gulmez and Yardımcıoglu (2012) use panel causality and cointegration methods to analyze the relationship between R&D expenditures and economic growth for the period 1990-2010 in 21 OECD countries. They find a bidirectional long run causal relationship between R&D expenditures and economic growth

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whereby a 1 per cent increase in R&D expenditures was associated with 0.77 per cent increase in economic growth during the given period (Akcali and Sismanoglu, 2015; Ildırar et al, 2016).

The existing econometric evidence suggests that output elasticity varies across different sets of firms and countries. For instance, over the period 1963-1982 there was a significant variation in the R&D output elasticity across countries. Empirical evidence shows a very high and significant elasticity for Japan and Germany (0.25-0.30), a lower but significant elasticity for France (0.10-0.15) and an insignificant output elasticity estimate for the United Kingdom (Patel and Soete, 1985).

The study by Kafouros (2005) further uncovers a higher economic impact of R&D among high-tech firms, for those firms. He identifies a statistically significant R&D output elasticity of 0.11 (OECD, 2015, p.17).

$$d(Z)/Z = 0.28d(Y)/Y. \tag{5.3}$$

$$t \quad 1169529$$

$$R^2 = 1.00 \qquad DW = 2.01 \qquad \text{Period: 1974-2020}$$

$$N = 47 \qquad HSDT = 0.25 \qquad Vector = 1/(d(d((d(TF_{-1})))^2))$$

From Equation (5.4), it can be deduced that growth in investment, government spending, exports and imports played less significant roles than consumption growth, in enhancing innovation advancement during the 1974-2020 period. Thus, a 1 per cent increase in growth of consumption, investment, government spending, exports and imports could have caused annual innovation advancement to rise by 0.252, 0.035, 0.021, 0.021 and -0.048 per cent respectively during the given period. This result indicates that during the given period much of the contribution of output to innovation came from consumption of goods and services.

Individual end consumers may develop innovations for themselves. But generally, they do not protect their innovations with the available intellectual property rights. According to de Jong (2016b) a number of recent studies show that innovation by individual end consumers is substantial. But official innovation statistics on the household sector (HHS) are not available. Therefore, these findings imply that the level of household consumption can affect the level of innovation. Moreover, quantitative evidence indicates that for a longtime consumers have been innovating (von Hippel, 2005). They innovate for fun, desire to learn, to help others or to benefit out of the innovation process (Raasch and von Hippel, 2013; de Jong, 2016b).

Representative Nationally Surveys indicate that many individual consumers innovate, not for profit. Instead, they innovate to satisfy their everyday personal needs that they desire. Consumption is one of the drivers of innovation as supported by the evidence that in UK, Netherlands, USA, Japan, Finland and Canada; the estimated number of household sector innovators for each country in 2016 was 2.9, 0.772, 16.0, 4.7, 0.172, 1.6 million respectively. The HHS innovators spend little time and money to invest and solve their daily problems. However, collectively, their investment is enormous. Their total expenditures rhyme with the corresponding innovation expenditures met by commercial enterprises (Hippel et al., 2011).

$$d\log Z = 0.252 dlogCn + 0.035 dlogI + 0.021 dlogG + 0.021 dlogX - 0.048 dlogM. \quad (5.4)$$

$$t \qquad 37.03 \qquad 6.11 \qquad 10.43 \qquad 22.90 \qquad -26.98$$

$R^2 = 1.00$ $DW = 2.08$ $F = 8.75 \times 10^{11}$ Period: 1974-2020

$N = 47$ $HSDT = 0.07$ $Vector = 1/(d(d((d(TF_{-1})))^2))$

From Equation (5.5) it can be verified that a 1 per cent increase in growth of innovation, capital productivity and labor productivity could have led to a 1, 0.155 and 0.562 per cent increase respectively in the annual technological progress over the 1973 to 2020 period in Uganda. Betz (2011) suggests (a) technology to be a sub-system inside the innovation sub-system and (b) the innovation sub-system to be inside the technological innovation. Betz (2011) defines the technological innovation as the addition of invention and innovation. Nevertheless, he agrees with Hughes (1997) that technology is a complex system being revealed by the innovation process (King, 2020). From the arguments advanced by Betz (2011) we can conclude that both innovation and technology can be treated as endogenous variables and the relationship between them taken as interactive and the two variables reinforce each other.

Either capital productivity or labor productivity can lead to technological progress by causing firms to employ fewer inputs in the production process and thereby resulting in profits. And it is these profits that can be employed in the production process to enhance the replication or diffusion of the available technology.

Moreover, part of the profits and output obtained could be used in employing more capital or labor in the production process, thus causing more increase in input productivity growth and technological progress.

$$dlogA = 1.000 dlogZ + 0.155 dlogKp + 0.562 dlogLp. \quad (5.5)$$

$$t \qquad 239222 \qquad 19260.7 \qquad 9055.93$$

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$R^2 = 1.00$ $DW = 1.99$ $F = 3.25 \times 10^{10}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

However, from Equation (5.6) it can be discerned that growth in capital or labor can result in reduction in technological progress. Thus, a 1 percent increase in growth of both capital and labor could have individually caused annual technological progress to drop by 0.155 and 0.562 per cent respectively during the 1972 to 2020 period. Meanwhile, growth in capital (or labor quantity) might have had two effects: reducing capital productivity (or labor productivity) growth and enhancing output (economic) growth. In turn, it is the decline in productivity that could have caused reduction in technological progress and at the same time, it is growth in output that could have stimulated technological progress. It should be noted that productivity of an input is the real price of that input. Thus, when productivity of an input falls its price falls as well and the quantity bought of that input rises, vice versa.

$$dlogA = 3.537dlogZ - 0.155dlogK - 0.562dlogL. \qquad (5.6)$$

t 10005417 -13215310 -6428363

$R^2 = 1.00$ $DW = 2.02$ $F = 4.04 \times 10^{14}$ Period: 1972-2020

$N = 49$ $HSDT = 0.00$ $Vector = 1/\mathrm{d}(\mathrm{d}((\mathrm{X}/\mathrm{A})^2))$

From Equation (5.7) it can be observed that a 1 per cent increase in growth of technology, capital productivity and labor productivity might have caused annual economic growth to rise by 3.547, -0.548 and -1.989 per cent respectively within the given period. The result implies that growth in capital productivity has two effects: (a) decreasing labor growth and (b) reducing profit growth.

While the decline in the capital employed in production reduces economic growth (by -0.548 per cent of growth), the profits that have accrued during the production process is employed to stimulate in a commensurate way the technological progress and economic growth (by 0.548 per cent growth). Similarly, growth in labor productivity has two effects: (a) decreasing labor growth and (b) reducing profit growth. While the decline in the labor employed in production reduces economic growth (by -1.989 per cent growth), the profits that have accrued during the production process is employed to stimulate in a commensurate way the technological progress and economic growth (1.989 per cent growth).

Meanwhile, increase in technological progress could have caused a 1 percent rise in the annual economic growth (1 per cent growth) during the given period. Therefore, the net result of these interactions could have caused the net effect of technological progress on economic growth to be the sum of 0.548, 1.989 and 1.000 per cent and this sum ammounts to 3.547 per cent. Hence, these interactions could have set an internal equilibrium condition such that the technology versus the productivity of both labor and capital forces canceled out and left only the 1 per cent effect of technological progress on economic growth.

$$dlogY = 3.547dlogA - 0.548dlogKp - 1.989dlogLp. \quad (5.7)$$

t 239222 -19742.9 -9135.4

$R^2 = 1.00$ $DW = 1.99$ $F = 3.48 \times 10^{10}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

Results in Equation (5.8) indicate that during the 1973 to 2020 period a 1 per cent increase in innovation advancement and capital productivity growth could have caused the annual capital growth to rise by 3.537 and -1 per cent respectively.

The mathematical definition of capital productivity, in the long run tallies with inverse relationship between capital productivity and capital and is signified by the -1 parameter. From our finding we discover that technological progress destroys capital stock through capital productivity, but innovation advancement enhances capital stock growth.

The discovery implies that although through capital productivity, technological progress destroyed capital stock by 1.000 percent during the given period, the destruction was restored by innovation advancement at a rate of 3.537 percent yearly on average. Therefore, the annual 1.000 percent of capital destroyed by technological progress was restored on average by 3.537 percent of innovation advancement, while leaving an additional positive effect amounting to 2.537 per cent of innovation on capital stock. Hence, it appears as if the influence of innovation advancement on capital stock growth is always positive.

$$dlogK = 3.537dlogZ - 1.000dlogKp. \quad (5.8)$$

t 396455.8 -56575.11

$R^2 = 1.00$ $DW = 1.98$ $F = 2.00 \times 10^{11}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

Empirical results in Equation (5.9) show that during the 1973 to 2020 period a 1 per cent increase in innovation advancement and capital growth might have been responsible for the annual rise in capital productivity growth by 3.537 and -1 per cent respectively. According to the mathematical definition of capital productivity, in the long run there is an inverse relationship between capital productivity and capital signified by the -1 parameter. From Equation (5.9) the net effects of both innovation and technology (i.e., influence of capital through technology) on capital productivity is positive (2.537 percent).

$$dlogKp = 3.537dlogZ - 1.000dlogK. \quad (5.9)$$

t 53307 -56575

$R^2 = 1.00$ $DW = 1.98$ $F = 3.51 \times 10^9$ Period: 1973-2020

$N = 48$ $HSDT = 0.04$ $Vector = 1/d(d((TF_{-1})^2))$

It can be verified from Equation (5.10) that a 1 percent increase in innovation advancement and labor growth could have translated into a rise in yearly growth of labor productivity by 3.537 and -1.00 per cent respectively during the 1973 to 2020 period.

According to the mathematical definition of labor productivity, in the long run there is an inverse relationship between labor productivity and labor denoted by the -1 parameter. From Equation (5.10), it can be deduced that innovation always has a net positive contribution to labor productivity although labor growth has a negative influence on labor productivity growth, the negative effect is counteracted by technological advancement, by reducing the amount of capital employed in the process. In other words, it takes 2.514 per cent increase in technological progress to reduce capital growth by 1 per cent.

Schumpeter defined innovation as market of new goods, a new production method, a new market or raw material source, a new field of business, a new financial method or a new organization style. It is widely accepted that innovation increases the labor productivity. For instance, in the United States of America (USA) employment in agriculture declined steadily from 72 percent in 1820 to 2.5 percent in 1999. The declining share of agriculture was primarily as a result of vigorous productivity growth. In 1820, one farm family could on average feed and helped clothe 1.4 families. But in comparison, by 2000, one farm family could on average feed and clothe 40 families, excluding the export surplus that was consistently produced by American farmers. Meanwhile, between 1950 and 1990, U.S. agricultural output per unit of labor input grew at an average rate of 4.8 percent per year.

This rate was considerably higher than in other sectors of the economy (Scherer, 2010). The impressive productivity growth is due to countless technological innovations in use within the agricultural sector.

Such innovations were fertilizers and pesticides, better seed hybrids, and a host of labor-saving agricultural machines, complemented by the education and training of farmers in land grant universities and agricultural extension service facilities. Therefore, by law of capitalistic development it appears to hold true that “advances in productivity lessen the share of the work force (i.e., labor hours) in agriculture” (Scherer, 2010). Kurt and Kurt (2015) by using annual data over the 2000-2012 period determined the stationarity of the variables and conducted unit root tests. After that they estimate the labor productivity growth equations, and then establish the short-run relationships by using VAR and Granger causality tests. In the empirical analysis of results, the study finds a positive relationship between innovation and labor productivity.

$$dlogLp = 3.537dlogZ - 1.000dlogL. \qquad (5.10)$$

t 13636 -13709

$R^2 = 1.00$ $DW = 2.00$ $F = 1.97 \times 10^8$ Period: 1973-2020

$N = 48$ $HSDT = 0.25$ $Vector = 1/d(d((TF_{-1})^2))$

It can be verified from Equation (5.11) that a 1 percent increase in innovation advancement and labor productivity growth could have caused a rise in yearly growth of labor by 3.537 and -1.00 per cent respectively during the 1973 to 2020 period. According to the mathematical definition of labor productivity, in the long run there is an inverse relationship between labor productivity and labor denoted by the -1 parameter. From Equation (5.11) we discover that technological progress destroys labor stock but innovation advancement enhances labor growth. The discovery implies that although through labor productivity, technological progress destroyed labor stock by 1.000 percent during the given period, the destruction was restored by innovation advancement by 3.537 percent yearly on average. Therefore, the annual 1.000 percent of labor destroyed by technological progress through labor productivity, was restored on average by 3.537 percent of innovation advancement, while leaving an additional positive effect amounting to 2.537 per cent of innovation on labor stock. Hence, it appears as if the effect of innovation on labor is always positive.

Considering the relationship between innovation and job creation (employment), in general, empirical studies at micro-level widely confirm a positive link (Van Reenen, 1997; Evangelista and Savona, 2003; Piva and Vivarelli, 2005; Piva, Santarelli and Vivarelli, 2007; Mansury and Love, 2008; Ciriaci et al., 2013). However, at both the theoretical and experimental levels, literature particularly on the effect of innovation advancement on employment growth remain ambiguous and argumentative. Much of the literature has been on the historical debate (Say, 1803, 1964 edition). Since 1803 there have been numerous intellectuals trying to examine the displacement and replacement effects of innovation both form theoretical and empirical point of view. A body of extensive literature confirms that there is positive effect of product innovation on employment at the firm level. Meanwhile, the documentation on the evidences about process innovation is not well defined (Kaur and Nagaich, 2019).

Doms et al. (1995), find positive relationship between process innovation and employment growth in United States. Van Reenen (1997) conducts an investigation by obtaining firm-level panel covering the time period 1976 -1972 for UK. The author combines the London Stock Exchange database of manufacturing firms with the SPRU innovation database. After running the GMM-DIF estimates, the author finds a positive effect of innovation on employment. Controlling for fixed effects and dynamics and endogeneity makes the results from this study to become more robust.

Blechinger et al. (1998) also find evidence of positive effects of both product as well as process innovation on the employment growth in the Netherlands and Germany.

Meanwhile, Blanchflower and Burgess (1998) find positive effects of process innovation on the growth of employment by using two different panels of British and Australian Establishments (Kaur and Nagaich, 2019).

Greenan and Guellec (2000) employ panel data analysis on 15186 companies from manufacturing industries covering the time period 1986-1990 by combining firm-level panel data with innovation surveys. They find that the innovating firms create more jobs in comparison to the non-innovating firms. Ciriaci et al. (2016) conduct quantile regressions by using longitudinal dataset of 3304 Spanish firms covering the time period 2001-2009 with the aid of a combination of eight sets of the annual Spanish Community Innovation Survey (CIS). They find that smaller and younger innovative firms are more likely to have high and persistent growth in employment in comparison to the non-innovative ones (Kaur and Nagaich, 2019).

$$dlogL = 3.537dlogZ - 1.000dlogLp. \quad (5.11)$$

t 763234 -13709.2

$R^2 = 1.00$ $DW = 2.00$ $F = 6.32 \times 10^{11}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

It can be deduced that at equilibrium innovation advancement has the same effect on various dependent variables within the models built at equilibrium state such that:

$$KK_p \equiv LL_p \equiv A.TF \equiv P_o Y_p \equiv Z^{\frac{1}{1-\alpha-\beta}}. \quad (5.11a)$$

In the equilibrium state represented by Equation (5.11a) innovation advancement has the effect on growth of each of the eight dependent variables depicted in the model as follows:

$$d(\log(K)) = \frac{1}{1-\alpha-\beta} d(\log(Z)) - d(\log(Kp)), \text{ etc., etc.} \quad (5.11b)$$

Therefore, the coefficient $1/(1-\alpha-\beta)$ becomes the same in all the eight cases. Hence, from Equations (5.12) and (5.13) it can be verified that the influence of a 1 percent increase in innovation advancement on either per capita income growth or population growth (technology diffusion) is the same i.e., approximately 3.5 per cent per annum. Meanwhile, the effect of innovation on the third variable is in all the eight cases is -1% yearly as hypothesized.

$$d(Yp)/Yd = 3.634 d(Z)/Z - 1.026 d(PO)/PO. \quad (5.12)$$

t 228.68 -3557.5

$R^2 = 1.00$ $DW = 1.92$ $F = 1.27 \times 10^7$ Period: 1972-2020

$N = 49$ $HSDT = 0.06$ $Vector = 1/d(d((I)^2))$

Moreover, it appears as if the rate of innovation diffusion (measured by population growth rate of the innovation society assumed to be the same as the population growth rate of a country) is driven by the innovation advancement. Thus, from Equation (5.13) we discover that it is the innovation advancement that causes technology diffusion, income per capita growth and economic growth. Hence, enhancing innovation advancement would tantamount to the boosting of the entire components of an economic system in terms of increasing growth in income (GDP), technology, capital, capital productivity, employment, labor productivity, income per capita, technology diffusion, consumption, investment, government, exports, impots, disposable income, total factor, total spending and technology productivity.

$$d(PO)/PO = 3.542(Z)/Z - 0.975 d(Yp)/Yp. \quad (5.13)$$

t 228.47 -3557.5

$R^2 = 1.00$ $DW = 1.92$ $F = 1.26 \times 10^7$ Period: 1972-2020

$N = 49$ $HSDT = 0.05$ $Vector = 1/d(d((I)^2))$

From Equations (5.14) and (5.15) it can be observed that innovation advancement can promote growth of both total factor and technology. Thus a 1 per cent increase in innovation advancement could have caused a rise in either growth of total factor or technological progress by 3.537 per cent yearly coteries paribus.

$$dlogTF = 3.537dlogZ - 1.000dlogA. \quad (5.14)$$

t 26795441 -8427162

$R^2 = 1.00$ $DW = 1.83$ $F = 3.32 \times 10^{15}$ Period: 1972-2020

$N = 49$ $HSDT = 0.06$ $Vector = 1/d(d((A)^2))$

Meanwhile, results from Equations (5.15) imply technological progress and innovation advancement reinforce each other. Therefore, promotion of both technological progress and innovation advancement at the same time would be good for the enhancement of economic growth of the country.

$$dlogA = 3.537dlogZ - 1.000dlogTF. \quad (5.15)$$

t 11874853 -8427162

$R^2 = 1.00$ $DW = 1.83$ $F = 6.26 \times 10^{14}$ Period: 1972-2020

$N = 49$ $HSDT = 0.06$ $Vector = 1/d(d((A)^2))$

From Equation (5.16), we find that in Uganda during the 1972 to 2020 period, a 1 percent increase in innovation advancement could have caused household consumption to rise by 3.576% yearly. For instance, one of the innovation channels was agricultural innovation. Thus, in the early 2000s, the Agricultural Innovation System (AIS) and formation of the Cassava Innovation Platform (CIP) in Uganda were designed to stimulate interactions between researchers and farmers. Formation of the two systems lead to the development of improved cassava varieties through participatory plant breeding (PPB) and participatory variety selection (PVS). Meanwhile, the establishment of a community-based commercialized seed system called Cassava Seed Entrepreneurship (CSE) contributed to the rapid multiplication and dissemination of clean planting materials in Uganda (Ahimbisibwe, et al., 2020).

The household consumption expenditure per capita was used to measure the effect of CIP participation on rural household welfare. Data for the study were collected from the formal household survey conducted in the eastern, northern, and mid-western regions of Uganda. Empirical findings of the study show that the education, farm size, livestock size, access to credit, cost of cassava planting materials, access to extension service, access to training, and social group membership were significantly associated with CIP participation during the period under investigation. More importantly, the CIP participation resulted in a 47.4% increase in household consumption expenditure. Therefore, the implication of this important evidence is that there is need to promote agricultural innovation platform for improvement of rural livelihoods (Ahimbisibwe, et al., 2020).

$$dlogCn = 3.576dlogZ. \quad (5.16)$$

t 326.79

$R^2 = 1.00$ $DW = 1.76$ Period: 1973-2020

$N = 48$ $HSDT = 0.06$ $Vector = 1/d(d((TF_{-1})^2))$

From Equation (5.17) it can be discerned that a 1 per cent increase in innovation advancement could have caused the level of investment growth to rise by 3.597 per cent during the 1973 to 2020 in Uganda. However, most past studies explain the relationship between innovation and investment in terms of gross expenditure on innovation as a percent of aggregate investment. By looking at the relationship between the two variables in this way is equivalent to finding the effect of aggregate investment on innovation.

Alternatively, by using the data on our computed level of innovation and UN data on investment we find that throughout the given period the annual level of gross expenditures on innovation as a per cent of aggregate investment (GEII) was 0.3 per cent. The GEII formula is as follows: $GEII = \log(Z)/\log(I)$. To estimate the influence of investment on innovation the accurate formula can be used to establish the relationship represented in the formula. From the results given by the formula, it can be deduced that during the given period the gross expenditures on innovation as a per cent of aggregate investment was 0.3 per cent.

$$dlogI = 3.597dlogZ. \quad (5.17)$$

t 54.47

$R^2 = 0.9840$ $DW = 1.91$ Period: 1973-2020

$N = 48$ $HSDT = 0.05$ $Vector = 1/d(d((TF_{-1})^2))$

Empirical results in Equation 5.18 show that a 1 per cent increase in innovation advancement could have caused the level of government spending growth to rise by 3.498 per cent during the 1973 to 2020 in Uganda. However, by using the data on our computed level of innovation and UN data on government spending we find that throughout the given period the annual level of gross expenditures on R&D (innovation) as a per cent of government (GEIG) was 0.3 per cent. Our GEIG estimate is the same as that of MFPED (2009, p.4) for the government expenditure on R&D as a percentage of GDP estimated at 0.3% in 2005/06.The

GEIG formula employed is as follows: $GEIG = \log(Z)/\log(G)$. Using the same formula we find the same amount of contribution of gross expenditure on R&D to consumption, investment, government spending, exports, imports, disposable income, GDP, labor, total factor productivity, economic profit, total cost and capital.

$$dlog(G) = 3.498dlogZ. \quad (5.18)$$

$$t \quad 326.79$$

$$R^2 = 1.00 \quad DW = 2.15 \quad \text{Period: 1973-2020}$$

$$N = 48 \quad HSDT = 0.00 \quad Vector = 1/d(d((TF_{-1})^2))$$

Empirical results in Equation 5.19 show that a 1 per cent increase in innovation advancement could have caused the level of export growth to rise by 3.370 per cent during the 1973 to 2020 in Uganda. Other research studies also find that innovation advancement enhances export growth. Rodil, Vence, and Sánchez (2016) in their study combine various variables such as: research and development; innovation; structural characteristics and export behavior of firms. Their empirical evidence depicts positive relationship between innovation and exports. Dai, Sun, and Liu (2018) investigate firm level mark-up by using a large sample of Chinese manufacturing firms while utilizing the propensity score matching approach. They find complementary relationship between export and innovation. Azar and Ciabuschi (2017) employed the structural equation modelling to test the relationship between different types of technical innovation and firm export performance in 218 Swedish firms.

They find that innovation could have led to high export performance in Sweden during the period under investigation. Meanwhile. Some empirical results support the hypothesis that innovation boosts exports. Melitz (2003) uses the firm heterogeneity model of international trade and finds that exporters are more productive than non-exporters. The learning-by-exporting effect implies that exporting is important because it is through learning-by-doing from other foreign competitors, suppliers and customers, that firms become more productive (Wagner, 2007, Park et al., 2010).

Innovation is very essential for the improvement of value-added activity and achieving sustained growth, and investment in R&D is the key to innovation. Lin and Tang (2013) employ the theoretical two-country model that shows how export status affects R&D of a firm activity. Empirical evidence arising from testing their model by using ordinary least squares (OLS) regressions reveals that export status in China positively affects firm innovation. Thus, they find that in comparison to non-exporters, exporters increase their R&D intensity by more than 5 per cent, raise their R&D in expenditure by more than 33 per cent, and are 4 per cent more likely to engage in R&D activity (Lin and Tang, 2013).

However, studies that examine the relationship between exporting as a driver of innovation provide mixed evidence. Therefore, some research studies find a positive effect of exporting on innovation as follows: Kuncoro (2012) for Indonesia, Hahn and Park (2012) the Republic of Korea, Ito (2012) for Japan.

Meanwhile, Mairesse et al. (2012) from the People's Republic of China and some other research researchers find a reverse causality from innovation to exporting (positive effect of innovation on exporting) as follows: Damijan et al. (2010) for Slovenia, Cassiman et al. (2010) for Spain, Bratti and Felice (2012) for Italy, Halpern and Murakzy (2009) for Hungary, and Palangkaraya (2012) for Australia (Lin and Tang, 2013).

Moreover, some researchers have found more empirical evidence confirming the positive effect of innovation on export performance in developing countries (Heredia et al., 2018; Pla-Barber and Alegre, 2007; Silva et al., 2017). Therefore, it appears as if growth in both innovation and exports reinforce each other.

$$dlog(X) = 3.370 dlogZ. \qquad (5.19)$$

t 52.37

$R^2 = 1.00$ $DW = 2.13$ Period: 1973-2020

$N = 48$ $HSDT = 0.05$ $Vector = 1/d(d((TF_{-1})^2))$

From Equation (5.20) we coin a hypothesis that growth in innovation advancement causes a decline in import growth. But the result of our empirical finding in Equation (5.21) rejects it. Instead from Equation (5.20) we find that a 1 per cent growth in innovation advancement could have caused a rise in import growth by 3.623 per cent yearly in the country during the 1974 to 2020 period. Such an outcome could have been due to the fact that innovation advancement might have affected import growth through export growth since export is the sum of import and net export. During the given period Uganda had balance of payments deficits (BD). Therefore, during the given period export was equal to import plus BD. Hence, during this period innovation advancement had a relatively high potential of closing the BD gap where $\log(BD) = \log(X/M)$.

Chen, Zheng and Zheng (2017) find that importing intermediates tends to increase R&D intensity of importing firms. Meanwhile, exporting increases R&D intensity of importing firms. They also find that importing from high-income sources has a greater effect on innovation. But importing from low-income countries like China has spurred technological upgrades of firms operating in developed economies. Both Private and high-tech firms are prune to experience greater increases in innovation intensity. Little has been done to examine the relationship between imports and innovative activities. However, Boler et al. (2015) show that firms that use less expensive R&D, tend to increase their R&D investment as well as imports. Thus, contributing to the reduction in production costs at both the micro and the macro levels. On the other hand, importing has enhanced incremental innovation in Chinese firms by creating competitive pressure (Lu and Ng, 2012; Chen, Zheng and Zheng, 2017).

However, both theoretical and empirical findings conducted by Bernard et al. (2007) and Lopez (2005), show that firms that are engaged in international trade are larger and more productive than the ones that serve only domestic markets. Seker (2009) employs a detailed firm level dataset from the manufacturing sectors of 43 developing countries. The research finding shows that both exporting and importing of intermediate goods are related to higher growth performance and introduction of technological innovations. Therefore, the firms that perform both importing and exporting activities are the fastest growing ones. They are also the most innovative group of firms, followed by either only exporters or only importers. Bernard et al. (2007), examine firms from the United States engaged in international trade and find that 79 per cent of importers also export.

They also show that (a) both types of firms exhibit many similarities in their performance measures and (b) both exporters and importers are more productive, larger, capital and skill intensive than firms that do not have any trading relationships with the rest of the world (Seker, 2009).

$$dlog(M) = 3.623dlogZ. \qquad (5.20)$$

t 2123.42

$R^2 = 1.00$ $DW = 2.04$ Period: 1974-2020

$N = 47$ $HSDT = 0.00$ $Vector = 1/d(d((d(X_{-1}))^2))$

The HHS innovator has the liberty to operate either alone or collaboratively. In national surveys, it was found that 10% to 28% of all HHS innovations were collaborative efforts. Open collaborative innovations can be substantial and be alternatives to large-scale commercial products (Baldwin and von Hippel, 2011). The most common evidence is that of open-source software projects like Linux as an alternative to Microsoft Windows.

Another is open design projects like the RepRap in 3D printing being an alternative to the products offered by commercial suppliers like Stratasys. Thus, collaborative HHS innovations can fill the gap that commercial suppliers cannot adequately bridge. For instance, Wikipedia is more up-to-date and reliable than any commercial encyclopedia (de Jong, 2016b). The HHS innovators can enhance social welfare by developing innovations that are capable of substituting products of commercial producers by imposing price pressure, or driving producers to improve their quality. Alternatively, they can develop innovations capable of complementing producer offerings and increase the aggregated value of usage. Moreover, if producers adopt HHS innovations, the commercial value of their products outcompete traditional product development projects (e.g., Lilien et al., 2002; de Jong, 2016b).

$$dlogYd = 3.578dlogZ. \quad (5.21)$$

t 186.46

$R^2 = 1.00$ $DW = 1.79$ Period: 1973-2020

$N = 48$ $HSDT = 0.06$ $Vector = 1/d(d((TF_{-1})^2))$

Equation (5.22) tallies with early research works that innovators are persistently more profitable than non-innovators (Geroski et al., 1993; Roberts, 1999; Cefis and Ciccarelli, 2005). These studies employ empirical framework developed by Muller (1990). Their framework is an improvement of the model that Cubbin and Geroski (1987) as well Geroski and Jaquemine (1988) proposed. As a result, they consider profitability and its persistence in a Schumpeterian framework, driven by creative destruction (Schumpeter, 1934). Therefore, the empirical framework they adopt is composed of a simple, first order, autoregressive profit equation to model the threat of entry (Bartoloni, 2013). Consequently, Bartoloni (2013) uses an improved version of the standard autoregressive version of empirical framework (model) for the firm's profitability and finds that innovation is a significant driver of firm profitability.

Shasha (2021) uses data indicators got from CSMAR database of listed Chinese companies from 2015 to 2017 and finds that increase in R&D investment has a positive effect on the profitability of enterprises. "Therefore, enterprises can improve their profitability through technological innovation and increasing R&D investment." But if the R&D investment intensity is too high, it negatively effects the performance of the growing enterprises (Shasha, 2021). Yuchun and Yuanyan (2008) analyze the R&D information on A-share listed companies in manufacturing and information technology industries as sample data. Their results show that R&D investment has a positive effect on the profitability and growth ability of enterprises and this effect is cumulative but not instantaneous (Weygand, 1995). Up to date empirical evidence from numerous empirical studies using datasets from different countries have examined the effect of innovation on profitability.

The earlier studies examine the relationship between innovation and profitability at firm level were studies that utilized panel dataset of English firms (Geroski and Machin, 1992; Geroski, Machin, and Van Reenen, 1993).

Innovation plays an important role in firm profitability because it enhances firms to produce new brands, strengthen their position in the market, gain competitive advantage, and boost productivity (Ali, 1994: Greve and Taylor, 2000). Also, one of the early studies is by Leiponen (2000), uses a dataset composed on Finnish firms, to show that profitability of innovators is weaker than those of non-innovators and profitability gains of innovators is as a result of innovation (Calantone, Cavusgil, and Zhao, 2002; Cho and Pucik, 2005; Ken and Tsai, 2010; Anh et al., 2019).

$$dlog(\pi) = 3.311 dlogZ. \qquad (5.22)$$

t 38.84

$R^2 = 1.96$ $DW = 1.84$ Period: 1973-2020

$N = 48$ $HSDT = 0.06$ $Vector = 1/d(d((TF_{-1})^2))$

From Equation (5.23) it can be deduced that a 1 per cent increase in innovation advancement could have caused total cost growth to rise by 3.609 per cent during the 1973 to 2020 period. This result implies that innovation advancement could have affected growth in total cost through income growth because the relationship between total cost and income (i.e., revenue) can be represented as follows: $TC = Y - W$, where TC is total cost, Y is income desired for meeting various demands, W is economic profit and $Y = Z^{[1/(1-\alpha-\beta)]}$. The result also shows that at equilibrium marginal cost equals marginal revenue so that $\partial(TC)/\partial(Yd) = \partial(Y)/\partial(Yd)$ where Yd is output in terms of disposable income. In other words, the equilibrium condition could be represented as follows: $\partial(TC)/\partial(Yd) = [1/(1-\alpha-\beta)]\partial(Z)/\partial(Yd)$.

$$dlogTC = 3.609dlogZ. \quad (5.23)$$

t 135.76

$R^2 = 1.00$ $DW = 1.84$ Period: 1973-2020

$N = 48$ $HSDT = 0.05$ $Vector = 1/d(d((TF_{-1})^2))$

In the usual short neoclassical model empirical results are as given in Equation (5.24) showing the effects of technological progress on innovation advancement measured by innovation coefficient is 0.282 per cent per annum. These results appear to show that technological progress influences innovation advancement through economic growth; by technological progress enhancing economic growth and the economic growth in turn induces the firms and research institution to perform more innovations. Thus, empirical results in Equation (5.24) appears to show that innovation advancement is promoted more by growth in labor and very little by growth in capital as indicated by the labor elasticity value (0.159) and capital elasticity (0.044) during the 1972 to 2020 period.

$$dlogZ = 0.283dlogA + 0.044dlogK + 0.159dlogL. \quad (5.24)$$

t 10802924 8416439 16168250

$R^2 = 1.00$ $DW = 2.24$ $F = 5.59 \times 10^{16}$ Period: 1972-2020

$N = 49$ $HSDT = 0.10$ $Vector = 1/d(d((Yd)^2))$

In Equation (5.25) above it can be deduced that in the short run, technological progress and innovation advancement exert almost the same amount of effect on economic growth and therefore they have nearly equal influence on each other as follows:

$$d(\log(Y)) = [1/(1-\alpha-\beta)]d(\log(Z))$$

and $$d(\log(Y)) = [1/(1-\alpha-\beta)]d(\log(A)),$$

where $[1/(1-\alpha-\beta)] = 3.55$ as given in Equations (5.14) and (5.15). The implication of these results is that: $d(\log(A)) = d(\log(Z))$ as supported by results in Equation (5.25). Therefore, either capital productivity or labor productivity cannot embed technology or innovation but can only cause innovation and technology. So that the effect of either labor productivity or labor productivity on innovation and technological progress is transmitted through labor growth or capital growth respectively. Thus, as capital productivity growth increases it reduces the amount of capital in the production process.

The result of using fewer capital inputs causes fewer goods and services as well as higher input prices. Therefore, the production costs rise leading to a fall in profits that could have been devoted to enhancing innovation advancement, leading to suppression of innovation growth. Similarly, as labor productivity growth increases it reduces the amount of capital in the production process. The result of using fewer labor inputs causes fewer goods and services as well as higher input prices. So, the production costs rise leading to a fall in profits that could have been be devoted to enhancing innovation advancement, leading to suppression of innovation growth.

$$dlogZ = 1.000dlogA - 0.155dlogKp - 0.562dlogLp. \qquad (5.25)$$

t 239222 -19741.99 -9135.36

$R^2 = 1.00$ $DW = 1.99$ $F = 3.48 \times 10^{10}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

The results from the usual neoclassical model in Equation (5.26) show that economic growth appears to be enhanced more by technological progress than by either capital growth or labor growth. Therefore, this behavior is supported by the fact that a 1 per cent increase in growth of technology, capital and labor could have caused annual economic growth to rise by 1.000, 0.155 and 0.562 per cent respectively during the 1973 to 2020 period.

$$dlogY = 1.000dlogA + 0.155dlogK + 0.562dlogL. \qquad (5.26)$$

t 33420938 29587462 59295791

$R^2 = 1.00$ $DW = 1.81$ $F = 2.91 \times 10^{16}$ Period: 1973-2020

$N = 48$ $HSDT = 0.00$ $Vector = 1/d(d((TF_{-1})^2))$

6. Conclusion

The paper uses the generalized least squares method to examine the effects of innovation advancement on economic growth in Uganda during the 1970 to 2020 period. Data employed in conducting empirical analyses were collected from the United Nations database. The paper is based on the neoclassical growth model with decreasing returns to scale because production often occurs within the feasible production region. Empirical findings show that a 1 per cent increase in innovation growth could have caused economic growth to rise by 3.55 per cent yearly in Uganda during the given period. Similarly, a 1 per cent increase in innovation growth could have caused the growth of another microeconomic variable to rise by approximately 3.55 per cent yearly in the country during the given period. Finally, we conclude that innovation was by far the greatest contributor to economic growth during the given period. Hence, we recommend the application of innovation advancement to a great extent to enhance Uganda's economic growth.

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