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Ur Rehman, Ijaz and Shahbaz, Muhammad and Kyophilavong, Phouphet

University of Malaya, Kuala Lumpur, Malaysia, COMSATS Institute of Information Technology, Lahore, Pakistan, National University of Laos,

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Do Technological Developments and Financial Development Promote Economic Growth: Fresh Evidence from Romania

Ijaz Ur Rehman
Department of Finance and Banking
Faculty of Business and Accountancy
University of Malaya, Kuala Lumpur, Malaysia
Email: ejaaz.1983@gmail.com
Phone: +603 (0) 146179742

Muhammad Shahbaz
Department of Management Sciences,
COMSATS Institute of Information Technology,
Defense Road, Off Raiwind Road, Lahore, Pakistan
Email: shahbazmohd@live.com
Phone: +92-334-3664-657

Phouphet Kyophilavong
Faculty of Economics and Business Management,
National University of Laos,
POBOX7322, NUoL, Vientiane, Laos.
Email: Phouphetkyophilavong@gmail.com

Abstract

We study the relationship between financial development, technological development and economic growth in Romania. We construct aggregate indices of financial development and technological development using principal component analysis. The ARDL bounds testing approach shows the presence of cointegration between financial development, technological development and economic growth. Financial development and technological development contribute to economic growth. Moreover, financial development leads technological development which Granger causes economic growth. Our empirical evidence suggest that economic growth is driven by financial development via technological development and that, in Romania,a stable financial system and capital market can facilitate technological innovations.

Keywords: Financial development, technological development, economic growth, Romania
JEL Codes: O31, O33, O47

Introduction

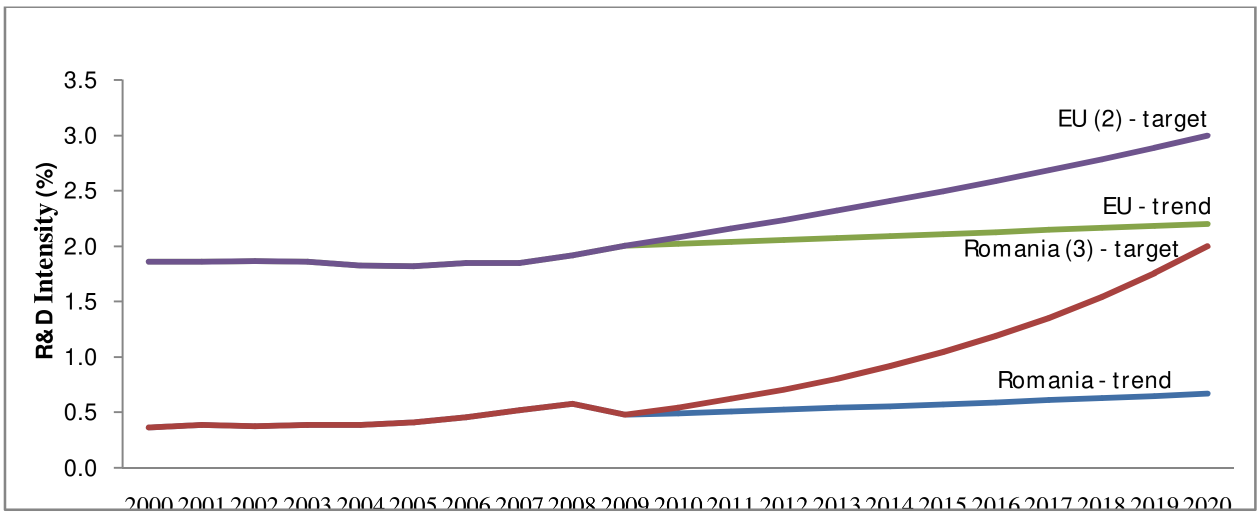
A country's technological innovation and economic growth are reflected via positive evolutions by most macroeconomic-stabilization, reduction in economic malaise and technological development. This study focuses on the contribution of financial development and technological development to economic growth in case of Romania. Soon after the access into European Union (EU), the main priority of Romania was to stimulate the economic competitiveness via technological advancements (Şipoş, 2009). When the global financial turmoil in 2008 punched the world financial markets, Romania was able to make a rapid recovery because of sensible macroeconomic management. Moreover, there was a need for long-term policies with the support of international financial institutions and other domestic institutions in Romania to absorb the adverse shocks of international financial crisis. Some of such reforms addressed short-term policies and the rest of the reforms were anchored in consistent long-term strategies to cope with the crisis[1]. Among such measures, technological innovation was also a priority for Romania to attain and sustain long-run economic growth.

Despite these efforts, Romania still sustains a very weak technological innovation performance in comparison with other EU countries. Romania, on one hand presents a positive economic growth trends based mostly on low value added exports and low cost labor, yet on other hand, Romania has a low level of technological innovation mechanisms and infrastructures. A very low level of public funding has caused such a situation where funding are injected in 10% of innovative firms with extremely low levels of expenditures not exceeding 3% of turnover. However, stimulated progress is made to promote the innovative culture in Romania[2]. Presently,

[1] Romania Overview: www.worldbank.org
[2] PRO INNO EUROPE: www.proinno-europe.eu

Romania does not have lucid national innovation policies. Explicit categories of innovation policies such as social, public sector innovation, non-technological, design and creativity are poorly framed in current research and development innovations (RDI) policy. However, demand-side innovation policies such as stimulating innovations regulations are relatively more developed (Necula, 2012).

Figure-1: Romania - R&D Intensity projections, 2000-2020

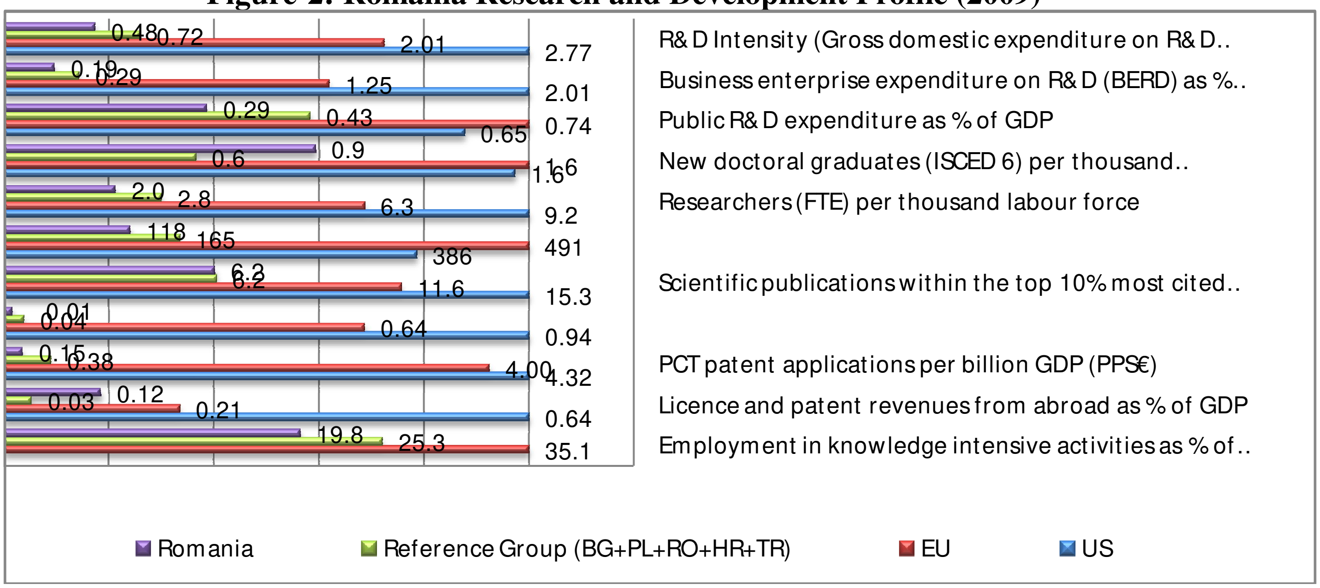


Source: Innovation Union Competitiveness Report (2011)

Romania appears to be a country with Low R&D level and hence, subject to a substantial gap in economic development as compared to other EU member's countries. However, despites of such gap, Romania have great growth potentials. The growth potentials in Romanian economy are characterized by the need for institutional structural and administrative reforms, fiscal gap, viable macroeconomic statistics, geographical position, existing natural resources and competitive labor costs (Ion and Victor, 2013). According to Innovation Union Competitiveness Report (2011) the

R&D capacity of Romania has improved to 0.48 % in 2009 from 0.37 % in 2000. Regardless of reasonable positive inclination toward R&D activities, Romania still sustains lowest score in R&D intensities in EU region. The report further documented that R&D potentials are expected to make 2.0 % contribution to national GDP in 2020, therefore, a significant increase in the R&D spending, both in relative and absolute terms will be helpful for Romanian economy to surge the economic competitiveness.

Figure-2: Romania Research and Development Profile (2009)



Source: Innovation Union Competitiveness Report (2011)

In addition to regulatory measures in technological innovation, reforms in financial sectors were also equally significant for Romania. During its first decade of transition from being a centrally planned economy to a free market economy, the financial system was mixed with growing capital markets, large state-owned domestic banks, and insurance firms and concurrently low levels of engagement by financial intermediaries and lack of contribution to GDP. During the last two decades, the banking sector of Central and Eastern European countries including Romania have experienced major changes because of the EU integration process. However, financial sectors reforms started in Romania in 1990s with the introduction of dual banking system and preserved a lofty contribution of the state in financial sector for several years (Gallizo et al. 2011).

In retrospect, keeping in view the above situation and the importance of such measures exploited by Romania during the last two decades, this study therefore, address two research questions. First, to what extent does financial development and technological development in Romania boost economic growth? Second, how do the relationship dynamics vary across financial development, technological development and economic growth in Romania? To address these research questions, we first construct an aggregated financial development index (FDI) and an aggregated technological development index (TDI) for Romania using various measures. Secondly, relationship dynamics are investigated using econometric method of cointegration. Moreover, we used structural breaks test to accommodate any breaks stemming in the series in response of the "innovation driven" reforms introduced by the Romanian government. The results of this research can significantly facilitate stakeholders and policy makers in devising short-term as well as long-term policies for financial development and technological innovation to sustain long-run economic growth in the case of Romania.

The rest of the paper is designed as following. Section 2reviews the literature related to financial development, technological development and economic development. Section 3 comprises detailed methodology of the construction of the technological development and financial development indices for Romania. Section 4 presents model construction and data collection.

Estimation strategy is introduced in section 5. Section 6 discusses empirical results. Section 7 concludes and contains policy implications.

2. Literature Review

Technological innovation is a concept that refers to the degree, nature and rate of technological change occurred (Smits, 2002). A technological innovation system is sort of an interaction among dynamic network of agents within a specific economic area of institutional infrastructure. Such dynamic networks struggle for diffusion, generation, and utilization of technology (Carlsson and, Stankiewicz, 1991). Jacobsson and Johnson, (2000) opined that the application of this approach may be three fold; in the sense of knowledge field, product, artifact, or satisfaction of a specific societal functions. Technological innovation has always been considered a primary element of long run economic growth. As economy moves from fragility to more unrelenting expansion, whether additional investment in technology will enhance economic growth or vice versa is a core policy issue across countries, because one of main distinctiveness of technological innovation and capabilities is that they are not homogeneously scattered across countries. In spite of international trade, foreign direct investment, communication and many other transfer of technology channels, access to old and new knowledge is far away from geographical uniformity (Archibugi and Coco, 2004).

One of the major factors that contribute to technological development across nations is human capital formation and R&D investment. For instance, it has been suggested in new growth framework that nation's efficiency and productivity largely depends on spillovers from R&D by other countries and own investment in R&D as well (Barro and Salai-i-Martin, 1995; Grossman and Helpman, 1991). R&D activities contribute to technological development in numerous areas such as transportation networks, information technology, industrial manufactures, communication, computers and peripherals, civil aerospace technology and pharmaceuticals (Gani, 2009).Solow (1957) pointed out that innovation is crucial for nation's competitive advantages and economic growth. Nevertheless, stirring and cultivating innovation is complicated, as Holmstrom (1989) figure out that innovation route is long, unpredictable and peculiar, thus engrosses potential probability of stoppage. Effective upholding of innovation necessitates well functioning capital markets that anchored vital role in allocating scant resources, managing risk, monitoring executives and thus reducing financing cost. Empirical evidence and existing theories suggest that credit market and equity market development have diverse effects on innovation.

Institutional structures play as the foundation of the concept of innovation system (Edquist and Johnson, 1997). For the sake of retention of sustainability, improvement in competitiveness and to enhance productivity, firms seek new technologies and capabilities. To achieve productivity and sustainability, firms need to push towards knowledge frontier to facilitate the innovation process and productivity. To acquire knowledge frontier, institutional environment and availability is financing are crucial factors to be considered. The literature advocates that possibility of innovation and level of productivity either through adoption or through innovation is contingent upon the availability of financing and institutional environment (Dabla-Norris et al. 2010).

Like other notable economic drivers, the importance of technological innovation for economic development does not need any explanation. The technological innovation where numerous dynamic network of driving forces intermingling in a specific business or economic domain involved in the generation, transmission, and exploitation of technology has significant impact on financial development as well as economic development. Sachs and McArthur, (2002) argued that country that innovates technologies will continue to lead in income per capita than countries that merely adopt technologies. This trend will continue and income gap between these two nations will persist even if the latter incorporates all the advancements made by former. Merely adopting technologies create lags in technology; consequently, continuation of lags in technology translates the effect into income gap. They further added that the relative pace of innovation and diffusion of technology determines the "catch up" between the adopter and innovator. It implies that high-tech exports bear a significant effect on the economic stability of exporting countries (Liu and Lin, 2005). Rosenberg, (2004) noted that technological innovation plays a vital role in economic growth in highly industrialized economies. However, the effect of technological innovation in low technology economies may also be immense (von Tunzelmann and Acha, 2005). However, (Fagerberg et al. 2009) claimed that economic struggling with development of appropriate technological capabilities might lag behind. Gerschenkron, (1962) found that some countries are spear heading at the technological front whereas others lag behind and those spears heading becomes a benchmark for those struggling. Kim et al. (2011) argued that innovation performance is not influenced by the technological collaboration with external firms rather external collaboration activities are normally centered on exchange of artifact manufacturing technologies and research & development.

Finance-growth relationship has been extensively discussed in the literature and this relationship has attained controversial consensus. One view is that economic growth is largely driven by financial development. Levine, (2003) for instance, suggested that financial development stimulates economic growth via efficient level of capital investment. Another view is that growth is driven by productivity instead of efficient capital investment in developed nations (e.g. Hall and Jones, 1999; Krugman, 1993). There are four strands in existing literature related to financial development and economic growth nexus. First, set of researches view that economic growth is driven by financial development (e.g. Shaw, 1973; King and Levine, 1993; Odedokun, 1996). Second thread opined that financial development is driven by economic growth (e.g. Levine and Beck, 2000; Khan and Senhadji, 2000; Jung, 1986). Third, few researches consider both economic growth and financial development are determinants of each other (e.g. Greenwood and Smith, 199; Luintel and Khan, 1999; Shahbaz, 2013; Shahbaz et al, 2013) and finally, some studies do not consider the relationship from either side (e.g. Lucas, 1988).

Financial development is considered as an important determinant of technological development both in developed and developing countries. It is argued that countries with mature financial system tend to high technological progress, which translates into higher quality output, and hence higher economic growth. Tadesse, (2007) argued that improving technological innovations and low-cost production methods can boost financial development and productivity in such a way that technologies espousal entails good amount of capital for the mobilization in well-developed financial system. It is noted that industries that are more dependent on external finance are more inclined towards growth in developed countries (Tadesse, 2007). Similarly, Hsu et al. (2012) examined the impact of financial market development on technological innovation growth in 32 emerging and developed countries. They identified the economic mechanism through the development of credit and equity markets influence innovation growth. Their results suggested that industries that depends more on external finance have more growth opportunities since they are in initial phase of life cycle and experience unequal innovation growth with better-developed financial markets.

Rajan and Zingales (1998) stated that financial development have significant implication for those sectors in economy that are more dependent on external finance since financial development reduces cost of external finance and such sectors/industries can cheaply finance their projects and eventually such activities are helpful in promoting economic growth. Another strand suggests that credit markets are less advantageous to innovative firms that are dependent on external finance compared to equity markets (Hsu et al. 2013). Brown, Martinsson, and Petersen (2012) argue that R&D intensive firms usually have inadequate and unsteady amount of internally generated cash flow to service debt. Hall and Lerner (2010) argue that knowledge assets that are fashioned by R&D investment are often insubstantial and partially entrenched in human capital. Thus, use of debt is largely constrained by inadequate collateral worth of intangible assets (Brown, Fazzari, and Petersen, 2009) that is physical assets are being preferred by banks over R&D investment to secure loan. Dominant banks suffocate innovation by pull out rents through their information creation and by defending reputable, low-tech firms (Hellwig, 1991; Rajan 1992). Brown, Fazzari, and Petersen (2009) stated that because of existing information quandary in high-tech industries, debt of poor substitute for equity financing in high tech-industries. Such problems comprise adverse selection and moral hazard. Former stem from the inherent risk of R&D Investment while in case of latter, high-tech industries can conveniently replace high risk for low risk projects.

In efforts to explain productivity growth, recent literature has emphasized the substance of R&D and finance. The relationship between finance and growth is analyzed in the framework of innovation- based growth Models developed by Aghion and Howitt (2009), Aghion et al. (2005) and Blackburn and Hung (1998). The models developed by these authors envisaged that imperfection in the financial markets led surge in the cost of monitoring and consequently push firms to hide successful innovation to evade repayment of Loan. Such imperfections can be deals by removing restrictions and thus it would facilitate persuading ideas to be patented and therefore fetches intensity in the technological sector. Endogenous growth theories underscore that hiding innovation production can be lessen through developing the financial system. For instance, Blackburn and Hung (1998) results suggest that firms have enticement to conceal successful R&D development to circumvent loan repayment, thus led to moral hazard problem. Such problem provides an opportunity to compel incentive –compatible load contracts at the expense of costly scrutiny. Their model further suggests that, financial deepening let the financial intermediaries to variegate amid large number of projects to reduce delegation cost. The less expensive scrutiny cost incites ideas generation and thus technological developments. In similar fashion, Aghion and Howitt (2009) stated that low screening and monitoring cost because of financial development largely mitigated agency problem and thus frequency of innovation are increased. Similarly, Aghion et al. (2005) developed innovation-based growth model and argued that firm can hide the outcomes of innovation and therefore repaying their loan. Underdeveloped financial market often caused low degree of the creditor protection, since underdeveloped financial system makes the fraud relatively cheap option for firms, therefore hampering to shape of new ideas. Researchers (e.g. Fritsch and Slavtchev, 2007) used knowledge production function to illustrate construction of innovative output in a multiple factor Cobb-Douglas production function that integrates innovative output to other R&D inputs. As for as innovative outputs are concerned, it is normally articulated in the context of innovation counts and patents since both innovation counts and patents are largely driven by the R&D input.

King and Levine (1993) analyzed the predictive ability of financial development towards long-run economic growth, productivity growth and capital accumulation for 77 countries over the period 1960-1989 by controlling the drivers of long-run growth. They measured financial development in the context of depth, bank and privy, such as financial intermediaries' size with respect to liquid liabilities as percentage of GDP. Whereas, Bank measures the degree to which the central and commercial bank distributes credit. Lastly, privy represents credit to private sector as a percentage of GDP for the purpose that allotting more credit to private sector will likely to motivating them to carry out a screening role. Their results suggest that proficient financial intermediaries have a first- order impact on economic growth. They further document positive influence of financial development on economic growth. Using GMM estimation, Shamim (2007) document cross-countries evidence of ICT measures, depth of financial sector and economic growth over the period of 1990-2002, their results suggest that better connectivity signified by number of internet users and numbers of mobile phone users considerably contributes to financial development and economic growth. In similar vein, Yartey (2008) articulate empirical evidence on the nexus of stock market development, credit, ICT development and output growth from 76 advanced and emerging countries. Their findings reveal that more developed is the country financial system, the more is development in ICT and diffusion and thus contribute to global digital divide.

3. The Construction of Technological and Financial Development Indices for Romania

3.1 The Index of Technological Development

Human capital formation and investment in research &development are the contributing factors of technological advancement (Gani, 2009; Shahbaz, 2012). Rodriguez and Wilson, (2000) measured technological achievement of nations as technological progress (ITP). They measured five components of technological progress namely fax machines, internet hosts, mobile phones, televisions, and personal computers. Later on 2011, UNDP used technology achievement index (TAI), which is composed of four aggregated measures (e.g. creation of technology, diffusion of recent innovation, diffusion of old innovation and human skills). TAI confines that how well a nation collectively contributes in generating, utilizing, and diffusion technology and building human skills to acquire knowledge (Márquez-Ramos and Martínez-Zarzoso, 2010). Márquez-Ramos and Martínez-Zarzoso, (2010) further explained the importance of different dimensions of technology achievement index. They categorized the construction of a technology achievement index into different dimensions. First is the number of *patents granted to residents*. The use of this indicator is significant because it reflects invention activities. Second dimension is *receipts of royalty and license fees from abroad*, which reflect accumulation of innovations, completed in the past and are still functional. Two further dimensions are used to determine the country technological innovation absorption level or transmission of old innovation namely, "*electricity consumption* and *number of telephones connections*" which included both landline and cellular connections. Moreover, electricity consumption is considered as proxy for machinery and equipment. They used diffusion of old innovations and creation of technology as proxies of potential absorptive capability. "*Internet hosts*" and "*high technology exports*" are used to measures the country technological innovation transformation potentials since high technology exports determines the country specialization in technology intensive products and internet hosts reflects the swift transmission of information and adaptation by firms. It has been suggested that human skills development and formation are also important for technological advancement. Márquez-Ramos and Martínez-Zarzoso, (2010) used two measurements of human skills development namely, "*mean years of schooling*" and "*gross tertiary enrolment ratio*". Both indicators reflects individual can be users of technology if they have basic education and that largely, the population will be able to develop skills in mathematics science, engineering and ultimately in technology creation.

Adapting similar dimensions of TAI developed by the UNDP and used by previous researches as disaggregated measures (e.g. Márquez-Ramos and Martínez-Zarzoso, 2010), we constructed a single index for technological development in case of Romania using Principal Component Analysis (PCA) rather than using disaggregated measures of technological achievements to avoid multicolinearity problem. The TAI index is also highly correlated with other national technological innovation indices such as (Archibugi and Coco, 2004) and communication technology index (Márquez-Ramos and Martínez-Zarzoso, 2010; Archibugi and Coco, 2004; Biggs, 2003). The advantages of using PCA are that it avoids the potentially high correlation among the different indicators (Sricharoen and Buchenrieder, 2005) and reduces the different components of observed variable to interpretable status (Kargbo and Adamu, 2010). This method has been widely used in the existing literature for constructing indices from several components in many areas including construction of environmental index (Kang, 2002), simple globalization index (Agenor, 2003) and financial development index (Khan and Qayyum, 2007; Kar et al. 2008; Hye, 2011). The first principal component yields the higher percentage of the total variations in the set of dimensions, which is consequently used to provide weight to each indicators and finally the weighted averaged indicators are summed into a single series[3].

We construct the technological development index using four major dimensions of technological achievements by Romania, namely, creation of technology, diffusion of recent innovation, diffusion of old innovation and human skills. We included resident patents, fees of royalty receipts and license from abroad, number of telephones connections, electric power consumption (KWH), high-technology exports, mean years of schooling and gross territory schooling rate to measure the technological development in case of Romania. We discard *interest hosts* indicators because of non-availability of data. The data for the rest of indicators were obtained from World Bank Development indicators (WDI) and Global Development Finance (GDF) over the period of 1985-2011. It is important to mention that there were certain limitations of the data for complete time span of few indicators. Hence, we used linear interpolation method to fill the missing fields for those indicators. The results of PCA are depicted in Table-1.Table-1 shows that the first principal component factor contributes 76% of variation, which has a better representation as compared to rest of the principal component factors. Therefore, we used the first eigen vector of each indicators to translate its weight on individual indicators of technological development. Table-1 further depicts that resident patents accounts 29% variation of the technological development. Other notable eigen vector are fees of royalty receipts and license from abroad (36%), high technology exports (30%), electric power consumption (40%).

[3] For detailed methodology of Principal Component method ,see Hye and Islam, (2012)

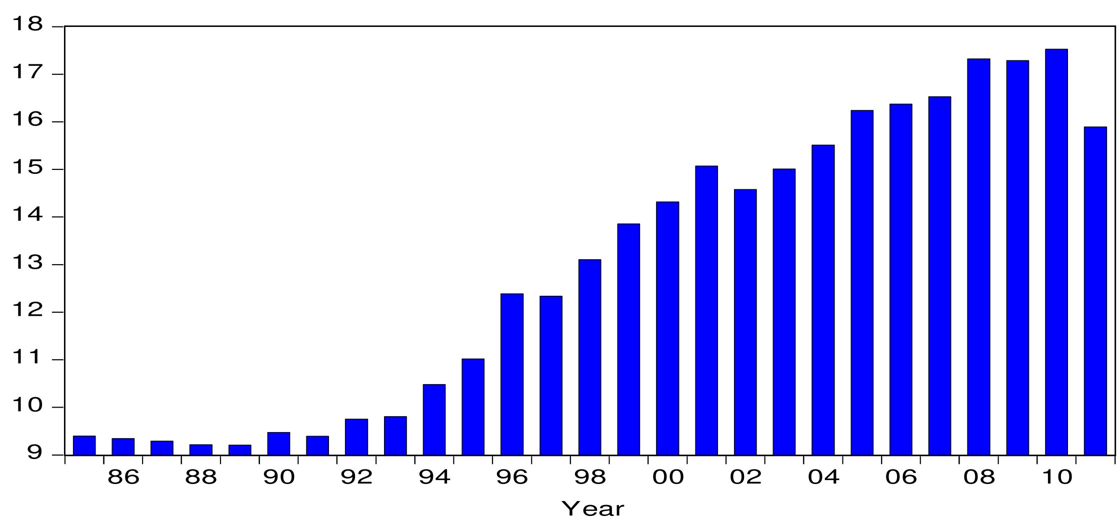
Table-1. Principal Component Analysis for Technological Development

	PCA1	*PCA2*	*PCA3*	*PCAC4*	*PAC5*	*PCA6*	*PCA7*
Eigen values	6.07	1.28	0.3	0.19	0.09	0.04	0.02
Variance prop.	0.76	0.16	0.04	0.02	0.01	0.01	0
Cumulative prop.	0.76	0.92	0.96	0.98	0.99	1	1
Eigenvectors							
Variable	*Vector 1*	*Vector 2*	*Vector 3*	*Vector 4*	*Vector 5*	*Vector 6*	*Vector 7*
Resident patents	0.29	0.56	0.39	-0.31	-0.16	-0.38	-0.32
RRL	0.36	0.3	0.34	0.41	-0.49	-0.13	0.46
TC	0.39	0.1	0.32	-0.13	-0.11	0.47	-0.09
EPC	0.40	0	0.12	0	-0.08	0.51	0.48
THE	0.30	0.49	-0.59	0.52	-0.08	0.1	-0.19
MYS	0.33	0.44	0.27	0.14	0.73	0.27	0
GTS	0.40	0.08	-0.11	-0.08	0.39	-0.49	0.6

Notes: RRL, Fees of Royalty Receipts and License from abroad, TC, Telephone connections, EPC, electric power consumptions, THE, High Technology Exports, MYS, Mean years of Schooling, GTS, Gross tertiary Schooling.

Figure-1displays the trend of the technological development index in the case of Romania over the past 25 years. It evident from Figure-1 that Romania has an overall increasing trend in technological development. Figure-1 further depicts that the Romanian economy experienced downward trend in technological development in the period of2009-2011.

Figure -1 Trend of Technological development in Romania



3.2 Financial Development Index for Romania

The earlier empirical studies on finance-growth nexus show that various proxies of financial development have been used in the past to construct financial development index. For instance, Khan and Qayyum, (2007) employed four proxies to generate financial development index in case of Pakistan such as ratio of the private credit, ratio of the stock market capitalization to GDP, total bank deposit liabilities to GDP and the ratio of clearinghouse amount to GDP. Similarly, Kar et al. (2008) constructed financial development index for Turkey by using three proxies namely, narrow money (M1)/output (Y), narrow money (M1)/ broad money (M2) and M2 (broad money)/ Y. In a similar vein, Hye, (2011) used four proxies such as the ratio of market capitalization to GDP, liquid liabilities (M3) to GDP, broad money (M2) to narrow money (M1) and domestic credit to private sectors as of GDP to regenerate financial development index in case of Pakistan. These studies then used Principal Component Analysis (PCA) to construct financial development indices.

Following previous studies (Tahir, 2008; Rioja and Valev, 2004, Rahman, 2004; Fase and Abma, 2003; Xu, 2000), we use three proxies to construct financial development index in case of Romania: domestic credit to private sector, broad money and market capitalization of listed companies (% of GDP). The selection of these proxies is largely related with data availability and subsequently subject to linearly interpolated process because for a few indicators the data was not completed. Using Principal Component Analysis (PCA) method, we constructed a financial development index for Romanian economy. The results of PCA are depicted in Table-2.

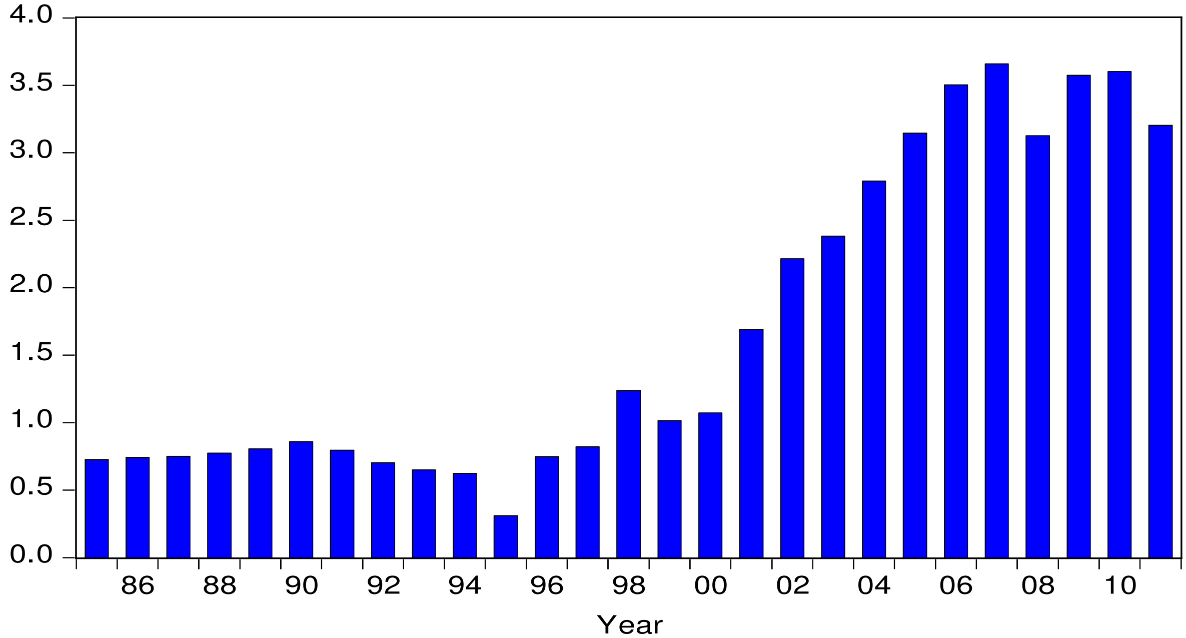
Table-2: Principal Component Analysis for Financial Development

	PCA1	*PCA2*	*PCA3*
Eigen values	1.654	1.101	0.244
Variance prop.	0.552	0.367	0.081
Cumulative prop.	0.552	0.919	1.000
Eigenvectors			
Indicators	*Vector 1*	*Vector 2*	*Vector 3*
DCP	0.629	0.480	-0.611
M2	0.470	0.873	0.407
MC	0.729	-0.091	0.679
Notes: DCP, Domestic credit to private sector (percentage of GDP), M2, Broad money (percentage of GDP), MC, Market capitalization of listed companies (percentage of GDP).			

Table-2 demonstrates that the two first principal component factors contribute 55% and 91% of variation, which has a better representation ability to weight it on the rest of the indicators as compared to rest of the principal component factors. Therefore, we used the first eigen vector of each indicator to translate its weight on individual indicator of financial development. Table-2 further depicts that domestic credit to private sector accounts 62% variations towards financial development whereas broad money contributes 47% and market capitalization of list firms contribute 72% toward financial development.

Figure-2 displays the financial development trend in Romania over the 1985-2011. It evident from Figure-2 that Romania has an overall increasing financial development trend. Figure-2 further depicts that Romania experienced a downtrend in financial development in the period of 1994-95 and again in 2009-2010. Interestingly, strong co-movement in technological and financial development is observed.

Figure -2: Trend of Financial development in Romania



IV. Model Specification and Data Collection

The aim of present study is to investigate the impact of financial development and technological development on economic growth using production function in case of Romania while the impact of capital and labor constant. The general form of production function is given as following:

$$Y_t = f(F_t,\ TA_t) \qquad (1)$$

Where, Y_t is domestic output, F_t shows financial development and TA_t is technological development. We have converted all the series into natural log-form. The empirical form of production function is modeled as following:

$$\ln Y_t = \beta_1 + \beta_F \ln F_t + \beta_{TA} \ln TA_t + \mu_i \qquad (2)$$

Where, $\ln Y_t$ denotes the natural log of real GDP per capita, $\ln F_t$ is natural log of financial development, natural of technological development is indicated by $\ln TA_t$ and μ is error term supposed to be having normal distribution.

The study covers the period of 1985-2011. The data on real GDP per capita is taken from world development indicators (CD-ROM, 2012). Similarly, data on financial development indicators such as, domestic credit to private sector, broad money (percentage of GDP), and market capitalization of listed companies (percentage of GDP) are also extracted from world development indicators (CD-ROM, 2012). Further, data on technological development indicators such as Fees of Royalty Receipts and License (FRRL) from abroad, telephone connections, electric power consumptions, high technology exports and gross and tertiary schooling are also mined in same fashion. Few technological development indicators data such as high technology exports and telephone connections was missing for few years. Such missing values in a series are linearly interpolated to fill the missing observations. Whereas, mean years of schooling data was combed from UNDP human development statistics.

5. Estimation Strategy

5.1: The ARDL Bounds Testing Approach to Cointegration

Different approaches are available in the empirical literature to test the long-run relationship among the variables. Most popular of them are Johansen co-integration test, Engle Granger test, Philip outliers, and autoregressive distributed lag (ARDL) bounds testing approach to cointegration. However, the advantage of using the ARDL cointegration test is that it can be applied regardless of the order of integration of the variables i.e. whether the variable are *I(0)* or *I(1)* or fractionally integrated. All the other approaches can only be applied if the variables are integrated at order *I(1)*. Therefore, this study employs the ARDL bounds testing approach to cointegration to examine the long-run relationship. The unrestricted error correction model (UECM) equation is given as following:

$$\begin{aligned}\Delta \ln Y_t = {} & \alpha_1 + \alpha_D D_1 + \alpha_Y \ln Y_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TA} \ln TA_{t-1} + \sum_{i=1}^{p} \vartheta_i \Delta \ln Y_{t-i} \\ & + \sum_{j=0}^{q} \vartheta_j \Delta \ln F_{t-j} + \sum_{k=0}^{r} \vartheta_k \Delta \ln TA_{t-k} + \mu_t \end{aligned} \quad (3)$$

$$\begin{aligned}\Delta \ln F_t = {} & \alpha_1 + \alpha_D D_2 + \alpha_Y \ln Y_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TA} \ln TA_{t-1} + \sum_{i=1}^{p} \alpha_i \Delta \ln F_{t-i} \\ & + \sum_{j=0}^{q} \alpha_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \alpha_k \Delta \ln TA_{t-k} + \mu_t \end{aligned} \quad (4)$$

$$\begin{aligned}\Delta \ln TA_t = {} & \alpha_1 + \alpha_D D_3 + \alpha_Y \ln Y_{t-1} + \alpha_F \ln F_{t-1} + \alpha_{TA} \ln TA_{t-1} + \sum_{i=1}^{p} \beta_i \Delta \ln TA_{t-i} \\ & + \sum_{j=0}^{q} \beta_j \Delta \ln Y_{t-j} + \sum_{k=0}^{r} \beta_k \Delta \ln F_{t-k} + \mu_t \end{aligned} \quad (5)$$

Where Δ denotes the 1^{st} difference operator and $D = 1,2,3.$ a dummy variable to accommodate structural break point determined by Zivot-Andrews unit root test and μ_t the error terms.

The F-statistic used to make decision about the hypothesis which is sensitive with lag order selection. The latter is chosen based on the minimum value of Akaike Information Criteria (AIC). Pesaran et al. (2001) developed F-test to determine the joint significance of the coefficients of lagged level of the variables. The absence of cointegration among the series (eq.

3-5) is, $H_0: \alpha_Y = \alpha_F = \alpha_{TA} = 0$ against the alternate of cointegration is, $H_a: \alpha_Y \neq \alpha_F \neq \alpha_{TA} \neq 0$. Pesaran et al. (2001) generated two asymptotic critical values, the upper critical bound (UCB) and lower critical bound (LCB) to make decisions about cointegration. The LCB is used if all the series are I(0), and the UCB otherwise. The computed F-statistics are based on, $F_Y(Y/F,TA)$, $F_F(F/Y,TA)$ and $F_{TA}(TA/Y,F)$ (equations (3-5) respectively. A long run relationship among the series is sustained if calculated F-statistic exceeds the UCB. There is no such relation, if the calculated F-statistic lies below the LCB. Our decision is inconclusive if the F-statistic lies between the LCB and the UCB. In such a case, error correction method may be suitable to investigate the cointegration. We use the critical bounds generated by Narayan, (2005) rather than Pesaran et al. (2001). The latter is suitable for large samples (T = 500 to T = 40, 000). Narayan and Narayan, (2005) points out that the critical in Pesaran et al. (2001) are significantly downwards and thus may produce biased outcome. The UCB and LCB by Narayan, (2005) are more appropriate for small sample (T = 30 to T = 80).

The stability of the long-run parameters is checked using CUSUM and CUSUMQ stability tests. In these tests if the plot of the residuals is well within the 5% critical bounds, then the long run parameters are considered stable and consistent. Finally, the model was tested for all diagnostic tests of normality, functional form, ARCH, white heteroscedasticity, and serial correlation tests.

5.2: The VECM Granger Causality Approach

After confirming cointegration we examine causality between pairs of the series which we do using the VECM. The VECM is restricted form of unrestricted VAR (vector autoregressive). All the series are considered endogenous in the system of error correction model (ECM) where the response variable is explained both by its own lags, lags of independent variables, and the lagged residuals. The error correction representationcan be developed as follows:

$$\begin{bmatrix} \Delta \ln Y_t \\ \Delta \ln F_t \\ \Delta \ln TA_t \end{bmatrix} = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix} + \begin{bmatrix} B_{11,1}\, B_{12,1}\, B_{13,1} \\ B_{21,1}\, B_{22,1}\, B_{23,1} \\ B_{31,1}\, B_{32,1}\, B_{33,1} \end{bmatrix} \times \begin{bmatrix} \Delta \ln Y_{t-1} \\ \Delta \ln F_{t-1} \\ \Delta \ln TA_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} B_{11,m}\, B_{12,m}\, B_{13,m} \\ B_{21,m}\, B_{22,m}\, B_{23,m} \\ B_{31,m}\, B_{32,m}\, B_{33,m} \end{bmatrix} \times \begin{bmatrix} \Delta \ln Y_{t-1} \\ \Delta \ln F_{t-1} \\ \Delta \ln TA_{t-1} \end{bmatrix} + \begin{bmatrix} \zeta_1 \\ \zeta_3 \\ \zeta_3 \end{bmatrix} \times (ECM_{t-1}) + \begin{bmatrix} \mu_{1t} \\ \mu_{2t} \\ \mu_{3t} \end{bmatrix} \tag{6}$$

Where $(1-L)$ is the difference operator; $ECM_{\text{t-1}}$ is the lagged error-correction term derived from the long-run cointegrating relationship; and μ_{1t}, μ_{2t} *and* μ_{3t} are serially independent random errors with mean zero and finite covariance matrix. The presence of a significant relationship in first differences of the variables provides evidence on the direction of the short-run causation while a significant *t*-statistic pertaining to the error correction term (*ECM*) suggests the presence of significant long-run causation. If cointegration is not detected, the causality test is performed without an error correction term (*ECM*). However, it should be kept in mind that the results of the statistical testing can only be interpreted in a predictive rather than in the deterministic sense. In other words, the causality has to be interpreted in Granger sense.

6. Results and their Discussions

First, we applied ADF, PP and Ng-Perron unit root tests to examine the integrating properties of financial development, technological development and economic growth in case of Romania. We used intercept and trend model for empirical analysis. Our results of ADF test reported in Table-

3 indicate that variables are not cointegrated at level but found to be stationary at 1st difference with intercept and trend. A same conclusion is drawn by PP and Ng-Perron unit root tests. This shows that the results are reliable. But, the results provided by ADF, PP and Ng-Perron unit root tests become invalid if structural exists in the series. The presence of structural beak in the series may reduce the power of unit root test and accept the null hypothesis when it is false and vice versa. So to overcome said issue, we applied ZA unit root test which determines single unknown structural break point stems in the series. The results of ZA test are reported in Table-4.

Table-3: Unit Root Analysis

	ADF		PP	
	I(1)		I(1)	
$\ln Y_t$	-5.445*		-6.775*	
$\ln F_t$	-6.985*		-5.221*	
$\ln TA_t$	-8.562*		-3.884*	
Ng-Perron unit root test at 1st Difference				
	MSB	MPT	MZa	MZt
$\ln Y_t$	-11.963*	-2.851	0.652	2.874
$\ln F_t$	-1.321**	-0.885	0.955	19.999
$\ln TA_t$	-2.057**	-0.446	0.725	33.825
Notes:* and ** show significance at 1% and 5% levels respectively.				

Table-4: Zivot-Andrews Structural Break Trended Unit Root Test

Variable	**A tLevel**			**At 1st Difference**		
	T-statistic	Time Break	Decision	T-statistic	Time Break	Decision
$\ln F_t$	-2.226 (2)	1992	Non-stationery	-6.701 (1)*	2001	Stationery
$\ln TA_t$	-2.397 (2)	2008	Non-stationery	-5.448 (3)**	1996	Stationery
$\ln Y_t$	-4.701 (1)	1991	Non-stationery	-7.907 (2)*	2000	Stationery
Notes: * and ** represents significant at 1% and 5% levels of significance respectively. Lag order is shown in parenthesis.						

It is necessary to choose appropriate lag order of the variables by applying unrestricted vector autoregressive (VAR). The reason is that F-statistic by the ARDL bounds testing approach varies with various lags. The results of lag length selection by the means of five criterions are depicted in Table-5. The results in the Table-4 portray that sequential modified LR test statistic (LR), final prediction error (FPE) and Akaike information criterion (AIC) selected the lag length as 4 but Schwarz information criterion (SC) and Hannan-Quinn information criterion (HQ) method select the lag length 2. As Schwarz information criterion (SC) gives the most parsimonious lag length, this study uses the lag length 2 for further analyses (Acquah, 2010).

Table-5: VAR Lag Order Selection Criteria

Lag	LogL	LR	FPE	AIC	SC	HQ
0	-87.72	NA	0.535	7.880	8.0368	7.929
1	-26.15	101.728	0.005	3.312	3.9024*	3.467*
2	-24.45	2.346	0.011	3.952	4.997	4.213
3	-14.13	11.623	0.011	3.832	5.311	4.219
4	12.059	22.788*	0.0034*	2.343*	4.226	2.856

Notes: * indicates lag order selected by the criterion. LR: sequential modified LR test statistic (each test at 5% level); FPE: Final prediction error; AIC: Akaike information criterion; SC: Schwarz information criterion; HQ: Hannan-Quinn information criterion.

Table-6: Results of ARDL cointegration Test

Variables	$\ln Y_t$	$\ln F_t$	$\ln TA_t$
Break Year	1991	1992	2008
F-statistic	10.497**	4.992	9.881**
Critical values	1% level	5% level	10% level
Lowerbounds	10.605	7.360	6.010[a]
Upperbounds	11.650	8.265	6.780
R^2	0.740	0.696	0.645
Adj-R^2	0.541	0.462	0.453
F-statistics	3.714**	2.980**	3.563**

Notes: *, ** and *** show the significance at 1%, 5% and 10% level respectively, [a] Critical values bounds are from Narayan (2005) with unrestricted trend and intercept.

Our next step is to apply the ARDL bounds testing approach to cointegration. We have accommodated dummy variable based on ZA unit root test. The structural break point in the series is indicated in 3rd row of Table-6. The ARDL bounds test of co-integration was used to check the long run relationship between technological development, financial development and economic growth. The results of ARDL test are reported in the Table-6.

Initially, it is noted that when economic growth is selected as a dependent variable, our computed F-statistic (10.497) turns out to be more than the upper bound at 5 percent significance level. Thus, this implies that that there is a long-run relationship among financial development, technological development, and economic growth. We could not find evidence of cointegration once we used financial development as dependent variables because our computed F-statistic (4.992) is less than lower critical bound. Similarly, we also found evidence of cointegration as we treated technological development as dependent variable. We find that our computed F-statistic (9.881) is higher than upper critical bound at 5 percent level of significance. This concludes that we have two cointegrating vectors as we used economic growth and technological development as predicted variables. This confirms the long run relationship between the variables in the presence of structural breaks over the period of 1985-2011 for Romanian economy.

The Table-7 reports the results of long-run as well as short run. In long-run, we find that, financial development adds in economic growth and it is statistically significant at 1 per cent level of significance. All else is same, a 1percent increase in financial development stimulates economic growth by 0.55 percent in Romania. This particular relationship implies that strong sensitivity of financial development would likely to promote economic activities in Romania by channeling fund to private sector and circulating the amount of broad money. Further, it is noted that technological development in Romania contributes to economic growth at 1 per cent level of significance. A 1 per cent increase in technological development adds in economic growth by 0.70 per cent, keeping other things constant. This implies that technological development enhances economic activity via creation of technology, diffusion of recent innovation, diffusion of old innovation and human skills. We find that, as compared to financial development, technological development has strong (positive) and significant impact on economic growth.

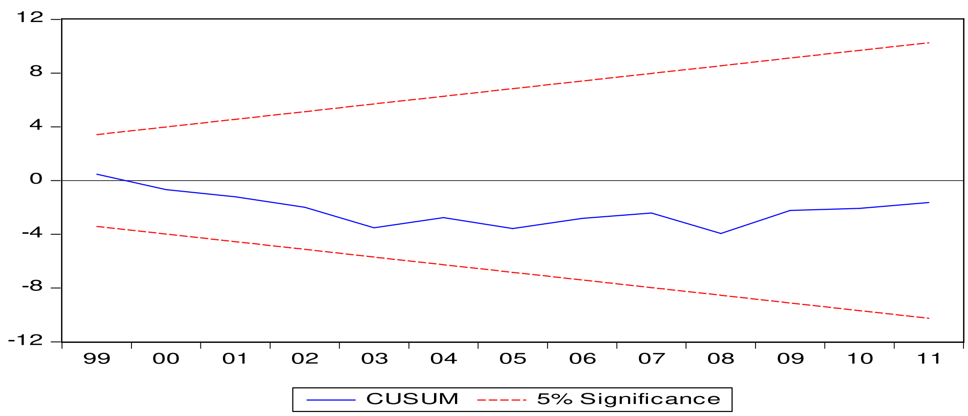
Table-7: Long-run and Short-run Analyses

Dependent Variable = $\ln Y_t$		
Long-run results		
Variable	Coefficient	t-Statistic
$\ln F_t$	0.552*	6.321
$\ln TA_t$	0.703*	8.652
Constant	9.888*	4.523
Short-run results		
Variable	Coefficient	t-Statistic
$\Delta \ln F_t$	0.153*	2.051
$\Delta \ln TA_t$	0.413*	6.258
ECM_{t-1}	-0.310*	-7.451
Constant	2.568*	3.568
Diagnostics Tests		
Test	F-statistic	Prob. value
$\chi 2$ normal	0.795	0.385
$\chi 2$ serial	0.245	0.658
$\chi 2$ arch	0.192	0.116
$\chi 2$ white	0.888	0.864
$\chi 2$ remsay	0.267	0.874
Notes: * and ** show significance at 1% and 5% levels respectively.		

In short-run, we find that financial development has positive and significant impact on economic growth. Similarly, technological development has significant and positive impact on economic growth. Our empirical analysis shows that technological development is major contributor to economic growth in Romania not only in short run but also in long run. Furthermore, Table-6 reports that estimate of lagged error term i.e. ECM_{t-1}symbolizes the speed of adjustment. The value of speed of adjustment is significant and negative, which demonstrates that shocks in short-run, is corrected towards equilibrium in the long-run. We find that economic shocks in the short-run are corrected by 31 percent towards long run equilibrium path in case of Romania. A high speed of ECM reflects recovery within 3 years and almost in 3 months process from economic shocks.

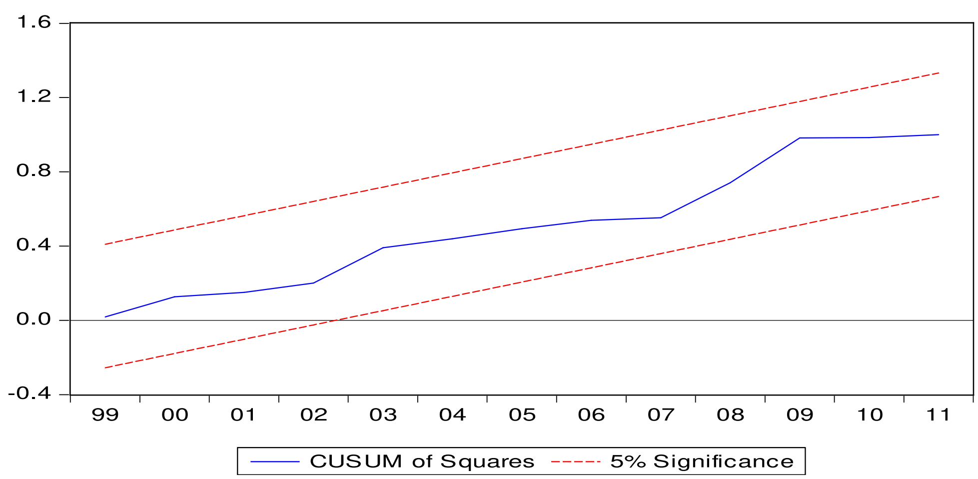
The long-run and short-run stability of parameters is checked by the means of CUSUM and CUSUMQ stability tests as shown in Figure-3 and 4. Since plots of residuals are in between the 5% critical bounds, thus yielding stable estimates. The empirical analysis complement previous literature on finance-growth nexus and provides empirical evidence that technological development takes place via financial development, which further translates it effect on economic growth both in the short run and long run in case of Romania. The finance-growth relationship findings are consistent with the literature that has documented that economic growth is driven by financial development (e.g. King and Levine, 1993; Odedokun, 1996; Shaw, 1973).The results also lend support to the arguments of Tadesse (2007) that facilitation of technological innovation through low cost production methods can stimulate financial development and economic growth. Technology adoption needs adequate funds, which could be easily mobilized by well-developed financial system. Financial development emancipates firms from the requirements of generating internal funds for finance innovations, which further translates technological progress through innovative capabilities of the firms. Therefore, nations with mature banking and capital markets should have better technological progress which further translate into productivity and economic growth.

Figure-3: Plot of Cumulative Sum of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Figure-4: Plot of Cumulative Sum of Squares of Recursive Residuals



The straight lines represent critical bounds at 5% significance level

We also diagnostic tests to check the robustness of the model and estimates. The robustness test results reported in Table-7indicate that the model attain the convergence by going through the diagnostic tests of normality, functional form, ARCH and white heteroscedasticity and serial correlation.

Table-8: Results of VECM Granger Causality Test

Variables			Short-run Causality			Long-run Causality
		$\ln Y_t$	$\ln F_t$	$\ln TA_t$		ECT_{t-1}
$\ln Y_t$		-	7.992* [0.002]	8.557* [0.001]		0.554** [-4.644]
$\ln F_t$		1.455 [0.145]	-	1.884 [0.456]		-
$\ln TA_t$		0.564 [0.395]	1.665 [0.612]	-		-0.624** [-5.336]
Notes:* and ** show significance at 1%, and 5% levels respectively. Figure in parentheses is the p-value for variables and t-statistic for ECT.						

Finally, we investigated the short- and long-run causality between financial development, technological development and economic growthby applying vector error correction model (VECM) Granger causality. Our resulst in Table-8 note that financial development Granger causes technological development and economic growth.The feedback effect is found between technological development and ecnomic growth. This shows that technology and economic growth are complementory.

In short-run, financial developmentand technological development Granger cause economic growth. The neutral effect is found between finnacial development and technological development. Economic growth does Granger cause finnacial development.

7. Conclusion and Policy Implications

This study was condcuted to assess the role of financial development and technological development in economic growth for Romanian economy using yearly data from 1985-2011.We applied the ARDL bounds testing coinetgration and the VECM Granger causality to examine the causal relationship between the variables.

Our results imply that cointegartion exists between finnacial development, technological development and economic growth in case of Romania. Financial development and technological development add in economic growth. Comparatively, technological development explains more variations in the economic growth. Financial development Granger causes technological development. Further, technological development and economic growth are complimentary. The overall results suggest that financial development in Romania plays a significant role in channeling fund to firms to stimulate the innovative capabilities. Conseqently, innovative capabilities facilitate in translating Romanian economy into technological development and thus in economic growth.Financial development supports technological development which further translates its effect into economic growth. The facilitation of technological innovation via low cost production methods can stimulate financial development and hence economic growth. Another plausible policy implication would be the creation of state-of-the-art research and technological incubation centers by authorizing several public or private sector research institution in a collaboration with private firms through special innovation grants, which can instigate new course in innovation research, which can potentially propel technological development and thus economic growth. Potential orientation of technological innovation for future policy measure may include targeted long-term innovation policies for improving technological transfer and updating the existing ICT infrastructure. The long-term technological innovation policy and subsequent support from government would fairly reduce the uncertainties involved in such process. Further, to strengthen the financial system and capital market in Romania, it is suggested that policy makers need to focus on the minimizing the risk exposures of Romanian banking sector from the spillover effect of other EU region financial sectors. It is also imperative to authorities in Romanian financial sector to focus on maintaining high capital advocacy to promote technological and economic development.

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