MACROECONOMIC DETERMINANTS OF TECHNOLOGICAL PROGRESS IN SELECTED EUROZONE COUNTRIES

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Abstract
Technological progress is one of the key factors that determine economic growth in both the exogenous growth models and the endogenous growth models. Therefore, technological progress is very important to achieve a sustainable economic growth. In this regard macroeconomic environment is one of the important determinants in the process of technological progress. This study investigates the relationship between technological progress and some key macroeconomic indicators in selected Eurozone countries during the period 1999-2012 by using panel Poisson regression and negative binomial regression. The findings from the both models demonstrated that economic growth, financial development, domestic savings, research and development expenditure and high technology exports had positive impact on technological progress.

Keywords: technological progress, economic development, financial development, inflation, foreign direct investment inflows, panel Poisson regression, negative binomial regression

JEL Classification: C35, O31, O33

Introduction

Sustainable economic growth is one of the main goals of all the countries in the world. Therefore, economic policymakers try to determine policies for achieving sustainable economic growth for the welfare of their public. On the other hand growth theories, both neoclassical growth theories and endogenous growth theories assert that technological progress is one of the key factors behind the long run economic growth. The pioneering studies of the neoclassical growth theory, Solow (1956) and Swan (1956), asserted that technological development is the cause of permanent economic growth. New economic growth theories also have attached importance to the technological progress in explaining the economic growth and endogenize the technology (See Romer (1986), Lucas (1988), Romer (1990)).
Eurozone consists of major developed countries such as Germany, France, Finland and the Netherlands in the world and second largest economy in the world. Therefore, we investigate the role of macroeconomic environment in success of their technological

progress in selected Eurozone countries (Austria, Belgium, Germany, Finland, France, Ireland, Italy, Netherlands, Portugal and Spain) during the period 1999-2012. This study will be one of the leading studies on the impact of macroeconomic environment on technological progress in Eurozone and contributes to the literature by filling the gap in this area. The rest of the paper is organized as follows. The next section outlines the empirical literature on the macroeconomic determinants of technological progress. Section 2 introduces the data and the methodology and Section 3 discusses empirical findings of the study and the study is finalized with conclusion.

1. Literature review

Technological progress is the key factor behind economic growth in both exogenous and endogenous growth models. In this regard many studies have been conducted on the impact of education, health, research of development (R&D), technological progress, government, accumulation of knowledge, financial innovation, and economies of scale. However, there have been relatively few studies on the macroeconomic determinants of technological progress. The major studies referenced here mainly reached the following findings on the macroeconomic determinants of technological progress:

- R&D expenditures had positive impact on technological progress (See Biatour and Kegels (2008), Khan and Roy (2011), Guloglu et al. (2012), Huňady and Orviská (2014)).
- Openness had positive impact on technological progress (Khan and Roy (2011)).
- Financial development had positive impact on technological progress (Akanbi (2011), Nwosu et al. (2013))
- Human development had positive impact on technological progress (Akanbi (2011))
- High technology exports had positive impact on technological progress (Guloglu et al. (2012))
- Foreign direct investment had positive impact on technological progress (Guloglu et al. (2012))
- Macroeconomic instability had negative impact on technological progress (Akanbi (2011))
- Interest rate had negative impact on technological progress (Guloglu et al. (2012))

Biatour and Kegels (2008) examined the relationship between multifactor productivity growth and business R&D, labor skills and ICT (Information and Communication Technologies) use in 20 Belgian market sectors during the period 1987-2005 by using dynamic panel regression and found that domestic R&D intensity had no statistically significant impact on multifactor productivity growth, while foreign R&D intensity had a positive impact on multifactor productivity.

Khan and Roy (2011) investigated the impact of macroeconomic indicator on innovation in BRICS countries during the period 1997-2010 by using panel regression and found that R&D expenditure and openness had positive impact on innovation. On the other hand Akanbi (2011) investigated the macroeconomic components of technological progress represented by total factor productivity in Nigeria during the period 1970-2006 by using Johansen cointegration and found that there was a negative relationship between technological progress and macroeconomic instability represented by general price level, while there was a positive relationship between technological progress, financial development and human development.

Guloglu et al. (2012) examined the relationship between technological progress represented by innovation (by the rate of patenting) and the macroeconomic variables including royalty payments, gross domestic expenditures on R&D, foreign direct investment, high-technology exports, openness to trade and the rate of interest in G7 countries during the period 1991-2009 by using panel Poisson regression and negative binomial regression techniques. They found that gross domestic expenditure on Research and Development, high technology exports, and foreign direct investment had positive impact on technological progress, while the rate of interest had negative impact on technological progress. Moreover there was no statistically relationship between technological progress and trade openness in G7 countries.

Nwosu et al. (2013) examined the relationship between total factor productivity and some macroeconomic variables in Nigeria during the period 1960-2010 by using vector error correction model. They found that domestic credit and exchange rate had positive impact on total factor productivity, while trade and openness had negative impact on total factor productivity. On the other hand Huňady and Orviská (2014) investigated the relationship among research and development expenditures, innovation, and economic growth in the European Union-27 countries during the period 1999-2011 by using panel regression and correlation analysis. They found that R&D expenditures were positively correlated with the number of patents.

2. Data and Methodology

2.1. Data

We investigated the major macroeconomic determinants of technological progress in 10 selected Eurozone countries (Austria, Belgium, Germany, Finland, France, Ireland, Italy, Netherlands, Portugal and Spain) during the period 1999-2012. Our study period and sample are dictated by data availability. The variables used in the econometric analysis, their symbols and data source were presented in Table 1.

We used the number of total patent grants for the technological progress, and took the variables including economic growth, financial development (domestic credit to private sector), macroeconomic instability (consumer price index), domestic savings (gross domestic savings), foreign direct investment inflows, high technology exports and R&D expenditure by considering theoretical and empirical literature.

Table no. 1 Variables used in the econometric analysis

Variable	Symbol	Source
Total patent grants	TPG	World Intellectual Property Organization (WIPO)
Real GDP per capita growth (annual %)	RGGR	World Development Indicators
Domestic credit to private sector (% of GDP)	DCP	World Development Indicators
Consumer price index (Base year 2005)	CPI	EUROSTAT
Foreign direct investment, net inflows (% of GDP)	FDI	World Development Indicators
Gross domestic savings (% of GDP)	GDS	World Development Indicators

Variable	Symbol	Source
High-technology exports (% of GDP)	HTE	World Development Indicators
Research and development expenditure (% of GDP)	RDE	World Development Indicators

2.2. Methodology

We firstly examined the properties of the time series. Therefore, cross-sectional dependence test was applied to determine whether there is dependence among the cross-sectional units, because cross-sectional dependence is important for the determination of further tests (Breusch and Pagan, 1980). The pioneering test for the cross-sectional dependence is Breusch and Pagan (1980) CDLM (Cross-sectional Dependency Lagrange Multiplier) test. CDLM test is biased when group average is zero, but individual average is different from zero. Pesaran et al. (2008) corrects this bias by adding variance and average to the test statistics. Therefore, this test is called as adjusted CDLM test $CDLM_{adj}$. In this study we used adjusted CDLM test for determining the cross-sectional dependence.

We used Hadri and Kuruzomi (2012) panel unit root test for the determination of unit root. Hadri and Kuruzomi (2012) panel unit root test considers both cross-sectional dependence among the panel units and unit root arisen from the common factors and enables the common factors to be. Moreover it enables autocorrelation to be and corrects autocorrelation by AR(p) process based on SUR (Seemingly Unrelated Regression) developed by Sul, Phillips and Choi (2005) in SPC (Sul-Phillips- Choi) method, by AR(p+1) process based on Choi (1993) and Toda and Yamamoto (1995) in LA (Lag-Augmented) method

We used panel Poisson regression and negative binomial regression models, which are generally used to count data consisting of zeros and small values, to investigate the impact of macroeconomic variables on technological progress (Greene, 2011).

The basic Poisson regression model is as follows:

$$Pr\ y_{it}\ = f\ y_{it}\ = \frac{e^{-\lambda_{it}}\lambda_{it}^{y_{it}}}{y_{it}!} \qquad (1)$$

where i indexes countries and t indexes years and $log\lambda_{it} = x'_{it}\beta,\ x_{it}$ is a vector of m regressors for unit i at time t. This basic Poisson Model are based on the assumption of $E\ y_{it}\ x_{it}\ = \lambda_{it} = V\ y_{it}\ x_{it}$. Also it is assumed that all the observations occurred randomly and independently across both countries and time (Cameron and Trivedi, 1998).

Poisson regression model assumes that conditional mean and variance are equal; this is the major shortcoming of Poisson regression model (Cameron and Trivedi, 1998). Alternative models such as negative binomial model have been developed to overcome the shortcomings of the Poisson model in later periods.

We also make estimation with negative binomial model which considers the overdispersion of the data. Negative binomial model enables each country's Poisson parameter to have its own randon distribution. The negative binomial model with fixed effects is as follows:

$$f\ y_{it}\ = \frac{\Gamma\ \lambda_{it} + y_{it}}{\Gamma\ \lambda_{it}\ \Gamma\ y_{it} + 1}\ \frac{1}{1+\theta_i}^{\lambda_{it}}\ \frac{\theta_i}{1+\theta_i}^{y_{it}} \qquad (2)$$

Also it is assumed that $E\ y_{it}\ \theta_i\ = \lambda_{it}\theta_i$ and $Var\ y_{it}\ \theta_i\ = \lambda_{it}\ \theta_i + \theta_i^2$ (Cameron and Trivedi, 1998)

Overdispersion is tested by a few methods such as Wald test, LR test and regression based tests. The LR test is generally used for the test of overdispersion, because log-likelihood function of the panel Poisson model and the negative binomial model could be obtained easily (Cameron and Trivedi, 1988). In this study we test the fixed effects models.
$H_0: E\ y_{it}\ = Var\ y_{it}$ (it means that negative binomial model reduces to the Poisson model)
$H_1: E\ y_{it}\ < Var\ y_{it}$ (it implies overdispersion)
$LR = -2\ LLFr - LLFu$ ($LLFr$ is the log-likelihood function of the Poisson model and $LLFu$ is the log-likelihood function of the negative binomial model)

3. Empirical Findings

3.1. Cross-Sectional Dependence

We applied $CDLM_{adj}$ test to determine whether there is cross-sectional dependence and the results of the test were presented in Table 2. The results demonstrated that there was cross-sectional dependence among the series. In other words any shock to any country affects the other countries.

Table no. 2 Results of $CDLM_{adj}$ cross-sectional test

Variables	Coefficient	Probability
TPG	3.665	0.001
RDE	4.782	0.024
HTE	3.274	0.015
FDI	4.071	0.000
RGGR	4.826	0.006
DCP	3.569	0.018
GDS	3.425	0.013
CPI	-4.421	0.000

3.2. Panel Unit Root Test

We analyzed the stationarity of the series by Hadri and Kuruzomi (2012) panel unit root test considering both cross-sectional dependence and the unit root from the common factors of the series. The results of the test were presented in Table 3 and the findings demonstrated that all the series were not stationary, but they became stationary after first differencing. Therefore, we will use the first differences of the variables in our model.

Table no. 3 Results of Hadri and Kuruzomi (2012) panel unit root test

Variables	Level Values (Constant&Trend)		First Level (Constant)	
	ZA^{SPC}	ZA^{LA}	ZA^{SPC}	ZA^{LA}
TPG	-2.631	-4.885	0.987*	0.836*
RDE	4.693	5.326	0.745*	0.114*
HTE	-12.885	-14.568	1.032*	1.642*
FDI	-2.522	-3.427	0.641*	1.457*
RGGR	-11.732	-10.674	1.347*	0.886*
DCP	2.944	4.321	1.643*	0.902*
GDS	-11.668	-14.562	0.447*	1.526*
CPI	-7.342	-5.733	0.902*	1.117*

* stationary at 0.05 significance level

3.3. Panel Poisson Regression Model

We used fixed effects specification, because our data set is comprised of Eurozone countries considering Baltagi (2008). Baltagi (2008) stated that fixed effects model should be used when the data set is comprised of specific countries. On the other hand we applied Hausman test and because p is smaller than 0.05 $\chi^2 = 24.56$, the null hypothesis was rejected and fixed effects model was used. The results of the fixed effects Poisson regression were presented in Table 4. The findings demonstrated that economic growth (RGGR), domestic credit to private sector (DCP), gross domestic savings (GDS), high-technology exports (HTE), R&D expenditure had positive impact on technology progress (TPG), while consumer price index (CPI) had negative impact on technology progress (TPG). On the other hand foreign direct investments (FDI) had no statistically significant on technology progress (TPG). When we examined the coefficients of the parameters, economic growth had the most significant impact on technology progress (TPG), while high technology export had the least significant impact on technology progress.

Table no. 4 Results of fixed effects Poisson regression model

Variables	Coefficient	Standard Error	Z	p
DRDE	0.169921	0.054585	3.112988	0.0023*
DHTE	0.159408	0.049474	3.222059	0.0017*
DFDI	0.032663	0.106002	0.308134	0.7585
DRGGR	0.440867	0.056978	7.737459	0.0000*
DDCP	0.224661	0.077314	2.905811	0.0046*
DGDS	0.162734	0.054363	2.993448	0.0034*
DCPI	-0.234584	0.079474	-2.951693	0.0038*
Log Likelihood		-82346.21		
Wald chi2 (7)		514.82		
Wald prob.		0.0021		

* statistically significant at 5%

3.4. Negative Binomial Regression Model

Poisson models are generally used under nearly homogenous conditions, while negative binomial models are used under the heterogeneous conditions (Lord et al. 2004:44). Although the Poisson distribution assumes that the mean and variance are the same, the data sometimes exhibit extra variation which is greater than the mean (this is called as overdispersion). Negative binomial regression is more flexible under overdispersion condition compared to the Poisson regression. If Poisson regression is used under overdispersion, the standard errors could be biased. The negative binomial distribution has one more parameter which adjusts the variance independently from the mean. We used Camaron and Trivedi (1998) method for the test of overdispersion. We found that p value is smaller than 0.05 as a consequence of LR test. Therefore, we estimated negative binomial regression by accepting overdispersion. The findings demonstrated that all the variables except FDI and CPI had positive impact on technological progress. FDI and CPI variables were found to be statistically insignificant. When we examined the coefficients, economic growth had the most significant impact on technological progress, while high technology exports had the least significant impact on economic growth.

Table no. 5 Results of negative binomial regression model

Variables	Coefficient	Standard Error	Z	P
DRDE	0.204246	0.050779	4.022285	0.0001*
DHTE	0.124317	0.058623	2.120605	0.0361*
DFDI	0.034153	0.089691	0.380783	0.7041
DRGGR	0.531732	0.092723	5.734624	0.0000*
DDCP	0.264793	0.122347	2.164283	0.0322*
DGDS	0.135062	0.059498	2.270041	0.0251*
DCPI	-0.117061	0.805645	-0.145302	0.8847
Likelihood-ratio test of alpha=0: chibar2(07)			926.03	
Log Likelihood			-678.93	
LR χ^2 (7)			67.23	

* statistically significant at 5%

Conclusion

Technology progress is key driver of economic growth both in exogenous and endogenous growth models. Therefore, we examined the macroeconomic determinants of technology progress in selected Eurozone countries by using two different panel count data models (Poisson model and negative binomial model).

The findings of panel Poisson regression model with fixed effects showed that economic growth, financial development, domestic savings, high-technology exports, R&D expenditure had positive impact on technological progress, while macroeconomic instability (inflation) had negative impact on technological progress. On the other hand foreign direct investment variable was found to be statistically insignificant.

The findings of panel negative binomial model demonstrated that economic growth, financial development, domestic savings, high-technology exports, R&D expenditure had positive impact on technological progress, while macroeconomic instability (inflation) and foreign direct investment variables were found to be statistically insignificant.

Our findings are consistent with the findings of few studies in the literature and it verified that macroeconomic stability, development of financial sector, domestic savings and R&D expenditure exhibit importance for the technological progress. Therefore, governments should consider these issues in policymaking and also take measures for the development of financial sector and encourage the public to make savings.

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