Macroeconomic Determinants of Technological Progress in Major Eurozone Member Countries

by

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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 exhibits importance for the decisions of the technological investments by both the governments and the firms which are one of the important determinants in the process of technological progress. This study investigates the relationship between technological progress and some key macroeconomic indicators including economic growth, financial development, inflation, foreign direct investment inflows, savings, high technology exports and research and development expenditures in major Eurozone countries during the period 1999-2012 by using panel Poisson regression and negative binomial regression. The findings from the both models indicated that economic growth, financial development, savings, research and development expenditures and high technology exports had positive impact on technological progress.

Key words: Macroeconomics, Technology, Eurozone.
JEL classification: C35, O31, O33

1 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. The 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)). Moreover extensive empirical studies verified that the technological progress is really an important component of the economic growth (See Du et al. (2014), Skare and Tomic (2014), Molinari et al. (2013)).

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 major 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 3 introduces the data and the econometric methodology and Section 4 presents and discusses empirical findings of the study and the study is finalized with conclusion.

2 Literature review

Technological progress is one of the key factors behind the long run 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 empirical studies on the macroeconomic determinants of technological progress in the literature. The major studies referenced here mainly reached the following findings on the macroeconomic determinants of technological progress:

- R&D expenditures (including import of technology) had a positive impact on technological progress (See Biatour and Kegels (2008), Gonçalves et al. (2008), Khan and Roy (2011), Guloglu et al. (2012), Zhang (2012), Huňady and Orviská (2014));
- Openness had a positive impact on technological progress (See Gonçalves et al. (2008), Khan and Roy (2011));
- Financial development had a positive impact on technological progress (See Akanbi (2011), Nwosu et al. (2013));
- Human development had a positive impact on technological progress (See Akanbi (2011), Zhang (2012));
- High technology exports had a positive impact on technological progress (See Guloglu et al. (2012));
- Foreign direct investment had a positive impact on technological progress (See Guloglu et al. (2012));
- Macroeconomic instability had a negative impact on technological progress (See Akanbi (2011));
- Interest rate had a negative impact on technological progress (See 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. On the other hand Gonçalves et al. (2008) investigated the determinants of the innovation for the industrial firms in Brazil and Argentine during the period 1998-2000 by using probit regression and found that the innovation heavily depended on the internal and external purchase of technological knowledge and global trade integration, while foreign capital decreased the innovation ability of the firms.

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 a 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 expenditure 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 a positive impact on technological progress, while the rate of interest had a negative impact on technological progress. Moreover there was no statistically significant 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.

3 Data and econometric methodology

3.1 Data

We investigated the major macroeconomic determinants of technological progress in major Eurozone member 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>
<thead>
<tr>
<th>Variables</th>
<th>Symbols</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consumer price index (Base year 2005)</td>
<td>CPI</td>
<td>EUROSTAT (2015)</td>
</tr>
<tr>
<td>Foreign direct investment, net inflows (% of GDP)</td>
<td>FDI</td>
<td>World Bank (2015b)</td>
</tr>
<tr>
<td>Gross domestic savings (% of GDP)</td>
<td>GDS</td>
<td>World Bank (2015c)</td>
</tr>
<tr>
<td>High-technology exports (% of GDP)</td>
<td>HTE</td>
<td>World Bank (2015d)</td>
</tr>
<tr>
<td>Research and development expenditure (% of GDP)</td>
<td>RDE</td>
<td>World Bank (2015e)</td>
</tr>
</tbody>
</table>

3.2 Econometric 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 of the panel, because cross-sectional dependence is important for the determination of further tests used in the econometric analysis (Breusch and Pagan, 1980). The pioneering test for the cross-sectional dependence is Breusch and Pagan (1980) $CD_{LM}$ (Cross-sectional Dependency Lagrange Multiplier) test. $CD_{LM}$ 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 $CD_{LM}$ test ($CD_{LMadj}$). The original form of $CD_{LM}$ test statistic is as follows:

$$ CD_{LM} = T \sum_{i=1}^{N} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 \sim \chi_{N(N-1)}^2 $$ (1)

then this statistic was adjusted by Pesaran et al. (2008) and becomes

$$ CD_{LMadj} = \left( \frac{2}{N(N-1)} \right)^{1/2} \left( \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} \hat{\rho}_{ij}^2 (T - K - 1)^{1/2} \right)_{\nu_{Tij}} \sim N(0,1) $$ (2)
\( \mu_{tij} \) represents the mean, while \( \nu_{tij} \) represents variance in this equation and the calculated test statistic exhibits an asymptotically standard normal distribution (Pesaran et al., 2008). The null hypothesis of the CD_{LMadj} test is that there is cross-sectional independence, while the alternative hypothesis is there is cross-sectional dependence. On the other hand test statistics and their probability values are calculated by bootstrapping. In this study we used adjusted CD_{LM} 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 Choi (1993) and Toda (2005) in SPC (Sul-Phillips and Choi 2005) in LA (Lag-Augmented) method. In a \( y_t \) series with a following data generation process:

\[
y_{it} = z_i \delta_t + f_i y_i + \epsilon_{it} \quad (3)
\]

\[
\epsilon_{it} = \varphi_i + \epsilon_{it-1} + v_{it} \quad (4)
\]

\( f_t \) represents common factors in these equation. If we express this series as AR(\( p \)), the series becomes:

\[
y_{it} = z_i \delta_t + \varphi_{1t} y_{it-1} + \ldots + \varphi_{pt} y_{it-p} + \bar{v}_{0t} \bar{y}_t + \ldots + \bar{v}_{pt} \bar{y}_{t-p} + \bar{v}_{it} \quad (5)
\]

The long run variance belonging to the estimation of this equation \( (\tilde{\sigma}^2_{it} = \frac{1}{T} \sum_{t=1}^{T} \bar{v}_{it}^2) \) is used for the calculation of both SPC variance \( (\tilde{\sigma}^2_{itSPC} = \frac{\tilde{\sigma}^2_{it}}{(1-\bar{\phi_i})^2}) \) and \( Z^A_{SPC} \) statistic as follows:

\[
Z^A_{SPC} = \frac{1}{\tilde{\sigma}^2_{itSPC}T^2} \sum_{t=1}^{T} (S^x_{it})^2 \quad (6)
\]

The (3) numbered series is expressed as AR(\( p + 1 \)) in LM method:

\[
y_{it} = z_i \delta_t y_{it-1} + \ldots + \bar{\varphi}_{tp} y_{it-p} + \bar{\varphi}_{tp+1} y_{it-p-1} + \bar{\varphi}_{0t} \bar{y}_t + \ldots + \bar{\varphi}_{pt} \bar{y}_{t-p} + \bar{\nu}_{it} \quad (7)
\]

The long run variance belonging to the estimation of this equation \( (\tilde{\sigma}^2_{vi} = \frac{1}{T} \sum_{t=1}^{T} \bar{v}_{it}^2) \) is used for the calculation of LA variance \( (\tilde{\sigma}^2_{vLi} = \frac{\tilde{\sigma}^2_{vi}}{(1-\bar{\varphi}_i)^2}) \) and \( Z^A_LA \) statistic is obtained as follows:

\[
Z^A_LA = \frac{1}{\tilde{\sigma}^2_{vLi}T^2} \sum_{t=1}^{T} (S^x_{it})^2 \quad (8)
\]

The null hypothesis of the test is that there is unit root in the series, while the alternative hypothesis there is not unit root in the series.

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 and he basic Poisson regression model is as follows (Greene, 2012):

\[
Pr(y_{it}) = f(y_{it}) = \frac{e^{-\lambda_{it}} \lambda_{it}^{y_{it}}}{y_{it}!} \quad (9)
\]

where \( i \) indexes countries and \( t \) indexes years and \( \lambda_{it} = x_{it}' \beta \), \( x_{it} \) 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. The negative binomial model enables each country’s Poisson parameter to have its own random distribution. The negative binomial model with fixed effects is as follows:

\[ f(y_{it}) = \frac{I(\lambda_{it} + y_{it})}{I(\lambda_{it})I(y_{it} + 1)} \left( \frac{1}{1 + \theta_i} \right)^{\lambda_{it}} \left( \frac{\theta_i}{1 + \theta_i} \right)^{y_{it}} \]  

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, 1998). The hypotheses of the test are as follows:

\[ H_0: E(y_{it}) = Var(y_{it}) \] (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)

4.1 Cross-sectional dependence test

We applied \( CD_{LMadj} \) 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 2: Results of \( CD_{LMadj} \) cross-sectional dependence test

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>TPG</td>
<td>3.665</td>
<td>0.001</td>
</tr>
<tr>
<td>RDE</td>
<td>4.782</td>
<td>0.024</td>
</tr>
<tr>
<td>HTE</td>
<td>3.274</td>
<td>0.015</td>
</tr>
<tr>
<td>FDI</td>
<td>-4.071</td>
<td>0.000</td>
</tr>
</tbody>
</table>

4.2 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 used the first differences of the variables in our model.

### Table 3: Results of Hadri and Kuruzomi (2012) panel unit root test

<table>
<thead>
<tr>
<th>Variables</th>
<th>Level (Constant &amp; trend)</th>
<th>First (Constant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ZA3PC</td>
<td>0.902*</td>
<td>0.987*</td>
</tr>
<tr>
<td>ZAL4</td>
<td>0.013</td>
<td>0.018</td>
</tr>
<tr>
<td>TPG</td>
<td>-2.631</td>
<td>-4.885</td>
</tr>
<tr>
<td>RDE</td>
<td>4.693</td>
<td>5.326</td>
</tr>
<tr>
<td>HTE</td>
<td>-12.885</td>
<td>-14.568</td>
</tr>
<tr>
<td>FDI</td>
<td>-2.522</td>
<td>-3.427</td>
</tr>
<tr>
<td>RGGR</td>
<td>-11.732</td>
<td>-10.674</td>
</tr>
<tr>
<td>DCP</td>
<td>2.944</td>
<td>-4.321</td>
</tr>
<tr>
<td>GDS</td>
<td>-11.668</td>
<td>-14.562</td>
</tr>
<tr>
<td>CPI</td>
<td>-7.342</td>
<td>-5.733</td>
</tr>
</tbody>
</table>

* stationary at 0.05 significance level

4.3 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 sample is comprised of specific countries. We also applied Hausman test and because the calculated p value 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, domestic credit to private sector, gross domestic savings, high-technology exports, R&D expenditure had positive impact on the technological progress, while consumer

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coefficient</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>RGGR</td>
<td>4.826</td>
<td>0.006</td>
</tr>
<tr>
<td>DCP</td>
<td>3.569</td>
<td>0.018</td>
</tr>
<tr>
<td>GDS</td>
<td>3.425</td>
<td>0.013</td>
</tr>
<tr>
<td>CPI</td>
<td>-4.421</td>
<td>0.000</td>
</tr>
</tbody>
</table>
price index had negative impact on the technological progress. On the other hand foreign direct investments had no statistically significant impact on the technological progress. When we examined the coefficients of the parameters, economic growth had the most significant impact on the technological progress (TPG), while high technology export had the least significant impact on technological progress.

Table 4: Results of fixed effects Poisson regression model

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coef.</th>
<th>Standard error</th>
<th>Z value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRDE</td>
<td>0.169921</td>
<td>0.054585</td>
<td>3.112988</td>
<td>0.0023*</td>
</tr>
<tr>
<td>DHTE</td>
<td>0.159408</td>
<td>0.049474</td>
<td>3.222059</td>
<td>0.0017*</td>
</tr>
<tr>
<td>DFDI</td>
<td>0.032663</td>
<td>0.106002</td>
<td>0.308134</td>
<td>0.7585</td>
</tr>
<tr>
<td>DRGGR</td>
<td>0.531732</td>
<td>0.092723</td>
<td>5.734624</td>
<td>0.0000*</td>
</tr>
<tr>
<td>DDCP</td>
<td>0.264793</td>
<td>0.122347</td>
<td>2.164283</td>
<td>0.0322*</td>
</tr>
<tr>
<td>DGDS</td>
<td>0.135062</td>
<td>0.059498</td>
<td>2.270041</td>
<td>0.0251*</td>
</tr>
<tr>
<td>DCPI</td>
<td>-0.234584</td>
<td>0.079474</td>
<td>-2.951693</td>
<td>0.0038*</td>
</tr>
</tbody>
</table>

Log Likelihood: -82346.21
Wald chi2 (7): 514.82
Wald prob. 0.0021

* statistically significant at 5%

4.4 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 5: Results of negative binomial regression model

<table>
<thead>
<tr>
<th>Variables</th>
<th>Coef.</th>
<th>Standard error</th>
<th>Z value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRDE</td>
<td>0.204246</td>
<td>0.050779</td>
<td>4.022285</td>
<td>0.0001*</td>
</tr>
<tr>
<td>DHTE</td>
<td>0.124317</td>
<td>0.058623</td>
<td>2.120605</td>
<td>0.0361*</td>
</tr>
<tr>
<td>DFDI</td>
<td>0.034153</td>
<td>0.089691</td>
<td>0.380783</td>
<td>0.7041</td>
</tr>
<tr>
<td>DRGGR</td>
<td>0.531732</td>
<td>0.092723</td>
<td>5.734624</td>
<td>0.0000*</td>
</tr>
<tr>
<td>DDCP</td>
<td>0.264793</td>
<td>0.122347</td>
<td>2.164283</td>
<td>0.0322*</td>
</tr>
<tr>
<td>DGDS</td>
<td>0.135062</td>
<td>0.059498</td>
<td>2.270041</td>
<td>0.0251*</td>
</tr>
<tr>
<td>DCPI</td>
<td>-0.117061</td>
<td>0.805645</td>
<td>-0.145302</td>
<td>0.8847</td>
</tr>
</tbody>
</table>

Likelihood-ratio test of alpha=0: chi-bar2(07) 926.03
Log Likelihood: -678.93
LR chi2 (7) 67.23

* statistically significant at 5%

5 Conclusions

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 major Eurozone member 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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References


**Yilmaz Bayar** was born in Malatya, Turkey in 1977. He completed Navy High School in 1995, graduated from Naval Academy in 1999 and served 13 years in the Navy. He was awarded a master degrees in the field of Accounting and Finance from Marmara University Institute of Social Sciences in 2006, in the field of International Economics & Finance from Bahcesehir University Institute of Social Sciences in 2007, and in the field of International Relations & Globalization from Kadir Has University Institute of Social Sciences in 2008. He was also awarded a PhD degree in the field of Economics in Istanbul University Institute of Social Sciences in 2012. He has worked as an Associate Professor Doctor in the Faculty of Economics and Administrative Sciences, Usak University, since September 2015.