EVALUATING THE EFFICIENCY OF EUROPEAN UNION INTEGRATION

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Abstract

Using data envelopment analysis approach, this study compares the relative performance of European Union (EU 15) nations against one another with seven economic variables as the benchmark parameters from 1993 to 2006. We find that all the participating nations were not equally efficient at the beginning of the economic integration in 1993. Economic integration did help in achieving convergence in economic performance of EU 15 nations, because thirteen of the fifteen nations were efficient in 1998. However, this study finds that after 1998, there is lack of convergence in the performance of EU 15 nations and some nations have performed more efficiently in contrast to other nations. The study points out the member nations that are lagging behind and make recommendations as to how they can improve their performance to bring them at par with other participating nations.

I. INTRODUCTION

The guiding principle behind economic integration/economic union is the concept of convergence in per capita income and/or per worker income among participating nations. European Union (EU) was created with this basic principle in mind. By making conditions equal across Europe, EU will be able to bridge the gap between the rich and poorer nations. Over the last fourteen years, EU has tried to create equal opportunities for the poorer nations and we try to find out if it helped poorer nations get richer and closer to rich nations in terms of GDP per capita as well as in terms of absolute amount of GDP. The purpose of this paper is to provide some comparative perspective on the growth rates of the original fifteen member nations of the European Union (EU). This study measures the effectiveness of the integration of Europe by benchmarking economic progress made by the original fifteen participating nations. In this paper, we use the *Data Envelopment Analysis* methodology to assess the relative performance of the 15 EU nations from 1993 to 2006. This paper builds on a previous study by Malhotra, Malhotra, and Mariotz (2005) (MMM hereafter) in which they benchmark European Union nations for the year 2004 only. We distinguish current study from MMM (2005)'s study by adopting a much larger database from January 1993 to January 2006. This will help us in tracking the progress made by the European Union in achieving convergence of economic performance of all the participating nations over a period of fourteen years.

Furthermore, by benchmarking European Union nations against one another for each of the last fourteen years, we will be able to find out if some nations have consistently performed well under the EU. By identifying the nations that have performed consistently well over a period of fourteen years, we can identify the factors that have contributed to their success so that other EU nations can structure their policies to benefit from economic integration. It will also help us track and understand the changes in performance of the EU over a period of time. Furthermore, we also investigate any trends in the performance of these countries over the last fourteen years.

The rest of the paper is organized along the following lines. Section II provides a summary of the previous literature on the European Union. We also include previous studies on applications of data envelopment analysis. In section III, we discuss the methodology used in this study. Section IV summarizes the empirical results. Section V provides summary and conclusion for this study.

II. PREVIOUS STUDIES

European Union Literature

Canova and Marcet (1995) study income convergence across European countries and report a high convergence rate, especially among members of the European Union countries. Paliwoda (1997) present selected statistics on Central and Eastern Europe to reflect the respective levels of current economic performance as well as expert projections as to where these economies are headed. According to Paliwoda (1997), a common objective shared by many Central and Eastern European nations is membership of the European Union together with the NATO defense alliance, so as to be better able to consolidate economic and political gains made to date. Canova (1999) analyzes the impact of EU's structural policies on the income disparities between countries and regions. Grimwade (1999) discusses the growth of the European Union and documents higher growth in the Eurozone after the integration. Wynne (2000) looks at how the economy of the euro area has fared under the single monetary policy, examines how successful the European Central Bank has been in fulfilling its mandate for price stability, and considers the prospects for the future. Despite the dramatic decline in the euro against the dollar over the course of 1999, the first year of EMU must be judged a success. Boldrin and Canova (2001) examine if EU subsidies help regions grow and bridge the gap between rich and poor regions. Garcia-Mila and McGuire (2001) evaluate the seventeen regional governments of Spain that receive grants from the European Union. This study evaluates the effectiveness of these grants and finds that these policies have not been effective in stimulating private investment or improving the overall economies of the poorer regions. Amuedo-Dorantes and Wheeler (2001) examines the impact that the European Union (EU) has exerted on Spanish economic activity. The main finding of the analysis is that the EU has significant impacts on the Spanish economy. The paper finds that shocks to EU output explain up to 63% of Spanish output. At longer time horizons, shocks to the EU's inflation rate and output combine to explain over 50% of the forecast error variance in Spanish inflation. Gacs (2003) analyzes how much and to what direction the inherited structure of the Central and East European candidate countries was transformed in recent years, and what this shift meant for their real convergence in the enlarged EU. A rearrangement of historical importance occurred across the main sectors contributing to GDP, in the framework of which services have been emancipated. Salih (2004) argues that the road to EU as a nation will not be as smooth as some European countries would have hoped. Structural incompatibilities, political rivalry and speculator's behavior are some of the factors that will affect the performance and unification of Europe. Ultimately, cooperation between rival nations is a vital factor to a successful unification of Europe, better global well being and trade and development. Malhotra and Mariotz (2005) measure the effectiveness of the integration of Europe by evaluating economic and socioeconomic progress made by fifteen participating nations since the Maastricht Treaty. They find that on the economic front, member nations have made good progress during the post-Maastricht Treaty period. However, on the socio-economic front, during the post-Maastricht Treaty, many member nations show deterioration in the performance. Beugelsduk (2005)’s study investigates whether there is evidence of convergence in the growth rates of current EU countries. The study also analyzes the role of structural funds allocated by the European Union in bringing about convergence.

Data Envelopment Analysis Literature

Recently, many studies have illustrated the use of DEA, a non-parametric methodology to analyze different aspects of mutual funds. The details of the DEA model are discussed in the next section. In contrast to other methodologies, DEA is one of the methods that have traditionally been used to assess the comparative efficiency of homogenous operating units such as schools, hospitals, utility companies, sales outlets, prisons, and military operations. More recently, it has been applied to banks (Haslem, Scheraga, & Bedingfield, 1999) and mutual funds (Haslem & Scheraga, 2003; Galagedera & Silvapulle, 2002; McMullen & Strong, 1998; Murthi, Choi, & Desai, 1997).

Murthi, Choi, & Desai (1997) examine the market efficiency of the mutual fund industry by different investment objectives. They use a benefit/cost non-parametric analysis where a relationship between return (benefit) and expense ratio, turnover, risk, and loads (cost) is established. They also develop a measure of performance of mutual funds that has a number of advantages over traditional indices. The DEA portfolio efficiency index (DEPI) does not require specification of a benchmark, but incorporates transaction costs. The most important advantage of DEA method as compared to other measures of fund performance is that DEA identifies the variables leading to inefficiencies and the levels by which they should be changed to restore the fund to its optimum level of efficiency. McMullen and Strong (1998) applied DEA to evaluate the relative performance of 135 US common stock funds using one, three, and five-year annualized returns, standard deviation of returns, sales charge, minimum initial investment, and expense ratio. They illustrate that DEA can assist in selecting mutual funds for an investor with a multifactor utility function. The DEA selects optimum combinations of investment characteristics, even when the desired characteristics are other than the two-factors specified in Capital Market Theory. The DEA enable the user to determine the most desirable alternatives, and pinpoint the inefficiencies in a DEA-inefficient alternative. Sedzro and Sardano (1999) analyzed 58 US equity funds in Canada using DEA with annual return, expense ratio, minimum initial investment and a proxy for risk as factors associated with fund performance. Further, they also find a strong relationship among the efficiency rankings using DEA, Sharpe ratios, and Morningstar data. Galagedera and Silvapulle (2002) use DEA to measure the relative efficiency of 257 Australian mutual funds. The further investigate the sensitivity of DEA efficiency to various input-output variable combinations. They find that more funds are efficient when DEA captures a fund's long-term growth and income distribution than a shorter time horizon. In general, the overall technical efficiency and the scale efficiency are higher for risk-aversive funds with high positive net flow of assets.

Haslem and Scheraga (2003) use DEA to identify efficiencies in the large-cap mutual funds in the 1999 Morningstar 500. They identify the financial variables that differ significantly between efficient and inefficient funds, and determine the nature of the relationships. They use Sharpe index as the DEA output variable. They find that the input/output and profile variables are significantly different between the Morningstar 500 (1999) large-cap mutual funds that are DEA performance-efficient and inefficient. Basso and Funari (2001) propose the use of DEA methodology to evaluate the performance of mutual funds. The proposed DEA performance indexes for mutual funds represent a generalization of various traditional numerical indexes that can take into account several inputs and outputs. They propose two classes of DEA indexes. The first class generalizes the traditional measures of evaluation using different risk indicators and subscription and redemption costs that burden the fund investment. The second class of indexes considers a multiple inputs-outputs structure. Thus, they monitor not only the mean return but also other features such as stochastic dominance and the time lay-out. Morey and Morey (1999) present two basic quadratic programming approaches for identifying those funds that are strictly dominated, regardless of the weightings on different time horizons being considered, relative to their mean returns and risks. They present a novel application of the philosophy of data envelopment analysis that focuses on estimating "radial" contraction/expansion potentials. Furthermore, in contrast to many studies of mutual fund's performance, their approach endogenously determines a custom-tailored benchmark portfolio to which each mutual fund's performance is compared.

Using data envelopment analysis approach, Malhotra, Malhotra, and Mariotz (2005) compare the relative performance of EU 15 nations against one another with seven economic variables as the benchmark parameters. Using the data for January 2003 MMM's study finds that there is lack of convergence in the performance of EU 15 nations and some nations have performed more efficiently in contrast to other nations. The purpose of this study is to investigate and analyze the relative performance of the original participating countries in the European Union since inception of the European Union. Using the economic data from 1993-2006, this study illustrates the use of data envelopment analysis (DEA) to evaluate the homogeneity of benefits of integration across the members of the European Union over the last thirteen years.

III. METHODOLOGY

The Data Envelopment Analysis Model

The Data Envelopment Analysis (DEA) (Charnes et al., 1978) is a widely used optimization-based technique that measures the relative performance of decision making units that are characterized by a multiple objectives and/or multiple inputs structure. The DEA methodology measures the performance efficiency of organization units called Decision-Making Units (DMUs). This technique aims to measure how efficiently a DMU uses the resources available to generate a set of outputs. The performance of DMUs is assessed in DEA using the concept of efficiency or productivity defined as a ratio of total outputs to total inputs. Efficiencies estimated using DEA are relative, that is, relative to the best performing DMU or DMUs (if multiple DMUs are the most efficient). The most efficient DMU is assigned an efficiency score of unity or 100 percent, and the performance of other DMUs vary between 0 and 100 percent relative to the best performance.

Consider a set of n observations on the DMUs. Let us define the following:

$j = 1,2,\ldots\ldots,n$ DMU.

$i = 1,2,\ldots\ldots,m$ inputs

$r = 1,2,\ldots\ldots,s$ outputs

Each observation, DMU_j, $j = 1,2,\ldots..,n$, uses:

x_{ij} – amount of input i for unit j, $i =1,2,\ldots\ldots,m$ and $j =1,2,\ldots.,n$.

y_{rj} – amount of output r for unit j, $r = 1,2,\ldots..,s$ and $j = 1,2,\ldots.,n$.

u_r – weight assigned to output r, $r = 1,2,\ldots..,s$

v_i – weight assigned to input i, $i =1,2,\ldots\ldots,m$.

The DEA methodology gives a measure of efficiency that is defined as the ratio of weighted outputs to weighted inputs. The most important issue in this method is the assessment of the weights. Charnes et. al. define the efficiency measure by assigning to each unit the most favorable weights. In general, the weights will not be the same for different units. Further, if a unit happens to be inefficient, relative to the others, when most favorable weights are chosen, then it is inefficient, independent of the choice of weights. Given these weights, the efficiency of a DMU in converting the inputs to outputs can be defined as the ratio of weighted sum of output to weighted sum of inputs.

$$\text{Efficiency} = \frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \qquad (3.1)$$

The weights for a DMU are determined using mathematical programming as those that will maximize the efficiency of a DMU subject to the condition that the efficiency of other DMUs (calculated using the same set of weights) is restricted to values between 0 and 1. The weights are chosen that only most efficient units will reach the upper bound of the efficiency measure, chosen as 1. Let us take one of the DMUs, say the oth DMU as the reference DMU under evaluation whose efficiency (E_o) is to be maximized. Therefore, to compute the DEA efficiency measure for the oth DMU, we have to solve the following fractional linear programming model:

$$\max E_o = \frac{\sum_{r=1}^{s} u_r y_{ro}}{\sum_{i=1}^{m} v_i x_{io}} \qquad (3.2)$$

Subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, \ j = 1,..,n \qquad (3.3)$$

$u_r \geq \varepsilon$, r = 1,…,s

$v_i \geq \varepsilon$, i = 1,….,m

Where ε is an infinitesimal or non-Archimedean constant that prevents the weights from vanishing (Charnes, et. al., 1994). When we solve the above mathematical program, we get the optimal objective function (3.2) that represents the efficiency of DMU_o. If the efficiency is unity, then the firm is said to be efficient, and will lie on the efficiency frontier. Otherwise, the firm is said to be relatively inefficient. To find the efficiency measure of other DMUs, we have to solve the above mathematical program by considering each of the DMUs as the reference DMU. Therefore, we obtain a Pareto efficiency measure where the efficient units lie on the efficiency frontier (Thanassoulis, 2001). The fractional mathematical programs are generally difficult to solve. To simplify them, we should convert them to a linear program format. The fractional program (3.2), (3.3) can be conveniently converted into an equivalent linear program by normalizing the denominator using the constraint $\sum_{i=1}^{m} v_i x_{io} = 1$. As the weighted sum of inputs is constrained to be unity and the objective function is the weighted sum of outputs that has to be maximized.

$$\max \sum_{r=1}^{s} u_r y_{ro} \qquad (3.4)$$

Subject to

$$\sum_{i=1}^{m} v_i x_{io} = 1, \qquad (3.5)$$

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, \ j = 1,..,n,$$

$$u_r \geq \varepsilon, \ r = 1,\ldots,s$$

$$v_i \geq \varepsilon, \ i = 1,\ldots.,m$$

This model is the CCR (Charnes, Cooper, and Rhodes) model. Similarly, a general input minimization CCR model can be represented as

$$\min \sum_{i=1}^{m} v'_i x_{io} \qquad (3.6)$$

Subject to

$$\sum_{r=1}^{s} u'_r y_{ro} = 1$$

$$\sum_{r=1}^{s} u'_r y_{rj} - \sum_{i=1}^{m} v'_i x_{ij} \leq 0, \ j = 1,..,n, \qquad (3.7)$$

$$u_r \geq \varepsilon, \ r = 1,\ldots,s$$

$$v_i \geq \varepsilon, \ i = 1,\ldots.,m$$

According to the basic linear programming, every linear programming problem (usually called the primal problem) has another closely related linear program, called its dual. Therefore, the dual of the output maximizing DEA program is as follows:

$$\theta^* = \min \ \theta \qquad (3.8)$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} \leq \theta x_{io}, \ i = 1,\ldots.,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{ro}, \ r = 1,\ldots,s \qquad (3.9)$$

$$\lambda_j \geq 0,$$

$$\theta \text{ unrestricted.}$$

If $\theta^* = 1$, then the current input levels cannot be reduced, indicating that DMU_o is on the frontier. Otherwise, if $\theta^* < 1$, then DMU_o is dominated by the frontier. θ^* represents the input-oriented efficiency score of DMU_o. The individual input reduction is called slack. In fact, both input and output slack values may exist in model (3.8)

$$s_i^- = \theta^* x_{io} - \sum_{j=1}^{n} \lambda_j x_{ij} \qquad i = 1,\ldots,m$$

$$s_r^+ = \sum_{j=1}^{n} \lambda_j y_{rj} - y_{ro}, \qquad r = 1,\ldots,s \qquad (3.10)$$

To determine the possible non-zero slacks after solving the linear program (3.8), we should solve the following linear program:

$$\max \sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta^* x_{io}, \; i = 1,\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro}, \; r = 1,\ldots,s \qquad (3.11)$$

$$\lambda_j \geq 0,$$

$$\theta \text{ unrestricted.}$$

DMU_o is efficient if and only if $\theta^* = 1$ and $s_i^{-*} = s_r^{+*} = 0$ for all i and r. DMU_o is weakly efficient if and only if $\theta^* = 1$ and $s_i^{-*} \neq 0$ and (or) $s_r^{+*} \neq 0$ for some i and r. In fact models (3.8) and (3.9) represent a two-stage DEA process that can be summarized in the following DEA model:

$$\min \quad \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$$

subject to

$$\sum_{j=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io},\ i = 1,\ldots,m$$

$$\sum_{j=1}^{n} \lambda_j y_{rj} - s_r^+ = y_{ro},\ r = 1,\ldots,s \qquad (3.12)$$

$$\lambda_j \geq 0,$$

$$\theta \text{ unrestricted.}$$

Table 1: Generalized DEA Models

Frontier Type	Input-Oriented	Output-Oriented
	$\text{Min } \theta - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$	$\text{Max } \phi - \varepsilon\left(\sum_{i=1}^{m} s_i^- + \sum_{r=1}^{s} s_r^+\right)$
Subject to	$\sum_{i=1}^{n} \lambda_j x_{ij} + s_i^- = \theta x_{io}\ i=1,2,\ldots,m$	$\sum_{i=1}^{n} \lambda_j x_{ij} + s_i^- = x_{io}\ i=1,2,\ldots,m$
CRS	$\sum_{j=1}^{n} \lambda_j x_{rj} + s_r^+ = y_{ro}\ r=1, 2,\ldots,s$;	$\sum_{j=1}^{n} \lambda_j y_{rj} + s_r^+ = \phi y_{ro}\ r=1,2,\ldots,s;$
	$\lambda_j \geq 0 \quad j=1,2,\ldots n$	$\lambda_j \geq 0 \quad j=1,2,\ldots n;$

VRS: Add $\sum_{j=1}^{n} \lambda_j = 1$; NIRS: Add $\sum_{j=1}^{n} \lambda_j \leq 1$; NDRS: Add $\sum_{j=1}^{n} \lambda_j \geq 1$

Where s are the slack variables; x represents input variables; y represent output variables; λ is a scalar factor, and θ and ϕ represent efficiency score of a DMU.

IV. DATA AND METHODOLOGY

The data for this study is obtained from *Countrydata.com*. Seven economic variables are used to evaluate the impact of European integration on the participating nations.

The variables have been defined by *Countrydata.com* as follows:

- **Current Account as Percentage of Gross Domestic Product (GDP)**: Estimated balance on the current account of the balance of payments, converted into US dollars at the average exchange rate for the year, expressed as a percentage of GDP, converted into US dollars at the average rate of exchange for the period covered.
- **Current Account as Percentage of Exports (XGS)**: Estimated balance on the current account of the balance of payments, converted to US$ at average rate, expressed as a percentage of total exports of goods and services (XGS), converted into US$ at exchange rate for period covered.
- **GDP per Head of Population**: Gross domestic product per head of population, converted into US dollars at the average exchange rate for that year.
- **Inflation**: Estimated annual inflation rate, expressed as the weighted average of the Consumer Price Index and calculated as a percentage change.
- **International Liquidity**: Estimated annual net liquidity expressed as months of cover and calculated as the official reserves of the individual countries, including

their official gold reserves calculated at current free market prices, but excluding the use of IMF credits and the foreign liabilities of the monetary authorities.

- **Real GDP Growth:** Annual change in estimated Gross Domestic Product, at a constant 1990 prices (for data in the 1990s), of a given country is expressed as a percentage increase or decrease.
- **Exchange Rate Stability**: It is measured by the annual percentage change in the exchange rate of the national currency against the US dollar (against the euro in the case of the US).

Data Envelopment Model Specifications for European Union

Besides the mathematical and computational requirements of the DEA model, there are many other factors that affect the specifications of the DEA model. These factors relate to the choice of the DMUs for a given DEA application, selection of inputs and outputs, choice of DMUs for a given DEA application, selection of inputs and outputs, choice of a particular DEA model (e.g. CRS, VRS, etc.) for a given application, and choice of an appropriate sensitivity analysis procedure (Ramanathan, 2003). Due to DEA's non parametric nature, there is no clear specification search strategy. However, the results of the analysis depend on the inputs/outputs included in the DEA model. There are two main factors that influence the selection of DMUs – homogeneity and the number of DMUs. To successfully apply the DEA methodology, we should consider homogenous units that perform similar tasks, and accomplish similar objectives. In our study, the countries are homogenous as they became part of the European Union. Furthermore, the number of DMUs is also an important consideration. The number of DMUs should be reasonable so as to capture high performance units, and sharply identify the relation between inputs and outputs. There are some simple rules of thumb that guide the selection of inputs and outputs, and the number of participating DMUs[1].

To study the performance of European Union countries, we consider seven factors: current account as percentage of GDP, current account as a percentage of XGS, inflation, GDP per head of population, real GDP growth rate, international liquidity, and exchange rate stability. Out of these seven factors, we specified inflation as input, because if a country is able to keep inflation down, it is an indicator of superior performance within the framework of the European Union guidelines. All other factors will be considered as output factors as a higher value of these variables improves the efficiency or performance of the country. Finally, the choice of the DEA model is also an important consideration. We should select the appropriate DEA model with options such as input maximizing or output minimizing, multiplier or envelopment, and constant or variable returns to scale. DEA applications that involve inflexible inputs or not fully under control inputs should use output-based formulations. On the contrary, an application with outputs that are an outcome of managerial goals, input-based DEA formulations are more appropriate. In addition, for an application that emphasizes inputs

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[1] The following are the guidelines for DMU model selection:

a. The number of DMUs is expected to be larger than the product of number of inputs and outputs (Darrat et. Al., 2002; Avkiran, 2001) to discriminate effectively between efficient and inefficient DMUs. The sample size should be at least 2 or 3 times larger than the sum of the number of inputs and outputs (Ramanathan, 2003).
b. The criteria for selction of inputs and outputs are also quite subjective. A DEA study should start with an exhaustive, mutual list of inputs and outputs that are considered relevant for the study. Screening inputs and outputs can be quite quantitative (e.g. statistical) or qualitative that are simply judgmental, use expert advice, or use methods such as analytical hierarchy process (Saaty, 1980). Typically inputs are the resources utilized by the DMUs or condition affecting the performance of DMUs. On the other hand, outputs are the benefits generated as a result of the operation of the DMUs, and records higher performance in terms of efficiency. Typically, we should restrict the total number of inputs and outputs to a reasonable level. As the number of inputs and outputs to a reasonable level. As the number of inputs and outputs increases, more number of DMUs get an efficiency rate of 1, as they become too specialized to be evaluated with respect to other units (Ramanathan, 2003).

and outputs, we should use multiplier version. Similarly, for an application that considers relations among DMUs, envelopment models are more suitable. Furthermore, the characteristics of the application dictate the use of constant or variable returns to scale. If the performance of DMUs depends heavily on the scale of operation, constant returns to scale (CRS) is more applicable, otherwise variable returns to scale is a more appropriate assumption.

In our study, the relationship among the European Union nations is an important consideration. Therefore, we select the envelopment models for our analysis. In addition, inflation is not a very flexible input that cannot be immediately controlled. Therefore, output-based formulation is recommended for our study. Furthermore, the performance of the EU nations does not depend on the scale of operations, thus variable returns to scale is safe assumption. Also, the structure of the DEA model (in envelopment form) uses an equation and separate calculation for every input and output. Therefore, all the input and output variables can be used simultaneously and measured in their own units.

IV. EMPIRICAL ANALYSIS

Each of the EU nations is a homogenous unit, and we can apply the DEA methodology to assess a comparative performance of these countries. The study evaluates the impact of the EU integration on achieving prosperity by tracking the gains (or losses) made by each member nation on economic front for each of the original 15 states of the union. Using the DEA methodology, we can calculate an efficiency score for the 15 nations on a scale of 1 to 100. We analyze and compute the efficiency of the EU nations for the period 1993-2006. Table 2 illustrates the efficiency scores of the original 15 states of the union from the year 1993-2006.Further, we also study the peers (model countries) for inefficient countries.

<Insert Table 2 about here>

Table 2 shows the progress made by the European Union nations in achieving convergence in economic performance of all participating nations. Table 2 shows that only eight out of fifteen countries were ranked efficient in 1993, but in 1998 thirteen out of fifteen nations were efficient and the remaining two were inefficient by a small margin only. Table 3 shows the efficiency scores of all the participating EU nations in the year 1993 along with their rankings.

<Insert Table 3 about here>

We present the score in percentage value varying between 0% and 100%. We find that the output efficiency of Spain, Portugal, Ireland, Denmark, Belgium, Germany, Austria, United Kingdom, and Netherlands is 100%. On the other hand, the output efficiency of Sweden, France, Finland, Italy, and Greece is 91% (1.10), 81% (1.23), 79% (1.27), 72% (1.40), and 45% (2.21), respectively. This means that the observed levels of current account as percentage of exports, exchange rate stability, current account as percentage of GDP, GDP per head of population, international liquidity, and real GDP growth are 1.10 times the maximum output level that Sweden can secure with its current inflation rate. The same rationale applies to France, Finland, Italy, and Greece. Table 4 illustrates the efficiency scores and the corresponding ranking of the fifteen original participating nations in the year 2006.

<Insert Table 4 about here>

United Kingdom, Sweden, Denmark, Ireland, and Finland are 100% efficient. Austria, Germany, Netherlands, Greece, Belgium, France, Spain, Italy, and Portugal are inefficient with output efficiency scores of 96% (1.04), 89% (1.35), 81% (1.23), 76% (1.33), 75% (1.33), 74% (1.35), 69% (1.44), 61% (1.63), and 36% (2.78), respectively. Figure 1 illustrates the trend in the graphical form for all countries from the year 1993 to 2006. As Austria, Germany, Netherlands, Greece, Belgium, France, Spain, Italy, and Portugal are inefficient; the next step is to identify the efficient peer group or countries whose operating practices can serve as a benchmark to improve the performance of these countries.

Table 5 illustrates the peer group for the inefficient countries.

<Insert Table 5 about here>

As shown in the Table 5, Denmark, and Ireland serve as peer for Austria. In addition, Austria is more comparable to Denmark (weight 77.78%) and less comparable to it's more distant peer Denmark (22.22%). Thus, Austria should scale up its GDP growth, exchange rate stability, international liquidity and other factors to make them comparable with Denmark. Similarly, Belgium has Denmark as the closest peer that it should emulate and Sweden as the distant peer country that can also be investigated. France has Denmark (88.89%) as its immediate peer and Ireland (11.11%) as its distant peer. Similarly, Germany has Denmark, Finland, and Sweden as its peers. Italy is 61% efficient and has Ireland as its immediate peer, and Denmark as its distant peer. Netherlands has Denmark, Sweden, and Finland as its immediate peers in decreasing order. Portugal has Denmark as its closest peer and Ireland as its distant peer. Finally, Spain has Ireland as its closest peer, and Denmark as its distant peer. Finally, Denmark serves as the closest peer, and the second closest peer for all the inefficient countries. Similarly, Ireland serves as the most immediate or immediate peer for most of the inefficient countries. On the other hand, Sweden is the distant peer for three of the inefficient countries. Therefore, Denmark is the most efficient country among all the European Union countries as not only is the Denmark 100% efficient, but it also serves as the role model for all other countries. Similarly, Ireland is also the next most efficient country among the group of EU countries. Finland serves as the immediate peer country for Germany and farther immediate peer country for Netherlands as the characteristics of Germany and Netherlands also resemble Finland. Thus, Finland is the next most efficient country among the EU nations. Finally, Sweden serves as the next immediate peer for Netherlands and Germany and the farthest immediate peer for Belgium. Again, this is quite expected as the characteristics of Belgium, Germany, and Netherlands match Sweden. Thus, Sweden is the last in the list of the most efficient countries in the year 2006. The efficient peer countries have a similar mix of input-output levels to that of the corresponding inefficient country, but at more absolute levels. The efficient countries generally have higher output levels relative to the country in question. The features of efficient peer countries make them very useful as role models inefficient countries can emulate to improve their performance. Furthermore, Denmark is used as an efficient peer to all Pareto-inefficient countries, so its frequency of use as an efficient-peer, expressed as a percentage of the number of pareto-inefficient countries, is 100%. Ireland is an efficient peer to six countries with a frequency rate of 67%. In addition, Sweden and Finland have the peer efficiency frequencies of 33% and 22% respectively. Thus, we have enhanced confidence that Denmark and Ireland are genuinely well performing countries as they outperform all the other countries. Furthermore, these countries are more likely to be a better role model for less efficient countries to emulate because their operating practices and environment match more closely those of the bulk of countries. Table 6 displays the benchmarking factor and the hit percentage of efficient country.

<Insert Table 6 about here>

After calculating the efficiency of a country using DEA, and identifying the efficient peers, the next step in DEA analysis is feasible expansion of the output or contraction of the input levels of the country within the possible set of input-output levels. The DEA efficiency measure tells us whether or next country can improve its performance relative to the set of countries to which it is being compared. Therefore, after maximizing the output efficiency, the next stage involves calculating the optimal set of slack values with assurance that output efficiency will not increase at the expense of slack values of the input and output factors. Once efficiency has been maximized, the model does seek the maximum sum of the input and output slacks. If any of these values is positive at the optimal solution to the DEA model that implies that the corresponding output of the country (DMU) can improve further after its output levels have been raised by the efficiency factor, without the need for additional input. If the efficiency is 100% and the slack variables are zero, then the output levels of a country cannot be expanded jointly or individually without raising its input level. Further, its input level cannot be lowered given its output levels. Thus, the countries are pareto-efficient with technical output efficiency of 1. If the country is 100% efficient but one slack value is positive at the optimal solution then the DEA model has identified a point on the efficiency frontier that offers the same level on one of the outputs as country A in question, but it offers in excess of the country A on the output corresponding to the positive slack. Thus, country A is not Pareto-efficient, but with radial efficiency of 1 as its output cannot be expanded jointly. Finally, if the country A is not efficient (<100%) or the efficiency factor is greater than 1, then the country in question is not Pareto-efficient and efficiency factor is the maximum factor by which both its observed output levels can be expanded without the need to raise its output. If at the optimal solution, we have not only output efficiency > 1, but also some positive slack, then the output of country A corresponding to the positive slack can be raised by more than the factor output efficiency, without the need for additional input. The potential additional output at country A is not reflected in its efficiency measure because the additional output does not apply across all output dimensions. Table 6 illustrates the slack values identified in the next stage of the DEA analysis. The slack variables for 100% efficient countries are zero. Therefore, United Kingdom, Sweden, Denmark, Ireland, and Finland are Pareto-efficient as the DEA model has been unable to identify some feasible production point which can improve on some other input or output level. On the other hand, for Austria, besides increasing the output level of current account as percentage of exports, there is further scope for increasing current account as percentage of exports by 4.45 (units), exchange rate stability by .13 (units), current account as percentage of GDP by 2.34 (units), international liquidity by 3.71 (units), and real GDP growth by .71(units). Austria can follow Ireland and Denmark as its role model and emulate their policies. Similarly, Belgium can reduce its inflation level by .75 units, and increase current account as percentage of exports by 2.72 units, exchange rate stability by 2.30 units, International liquidity by 4.98 units and real GDP growth by.34 units, while maintaining efficient levels equivalent to that of its peers—Denmark and Sweden. On the same lines, France can increase its output factors, current account as percentage of exports by 6.01, exchange rate stability by 2.86 units, current account as percentage of GDP by 2.89, International liquidity by 3.05 units and real GDP growth by.52 units to follow in the footsteps of its peers—Denmark and Ireland. Similarly, we can find the slack factors for Germany, Greece, Italy, Netherlands, Portugal, and Spain. Table 7 illustrates the slack values of the relevant factors for inefficient countries.

<Insert Table 7 about here>

V. SUMMARY AND CONCLUSIONS

Using data envelopment analysis approach, this study compares the relative performance of EU 15 nations against one another with seven economic variables as the benchmark parameters from 1993 to 2006. This study evaluates if EU delivered growth to member nations by creating equal conditions in terms of lower inflation through monetary policy coordination and lower budgetary deficits, and lower currency volatility through single currency. By studying the time period from 1993 to 2006, we also look at the variations in the performance of individual EU nations over a period of time under the European Union. This study shows that economic integration did move European Union nations towards convergence of economic performance till the year 1998. Our study shows that at the beginning of the economic integration, eight out of fifteen member nations showed 100 percent efficiency in 1993. European Union made good progress towards convergence of economic performance, because in 1998 thirteen out of fifteen member nations show 100 percent efficiency. In recent years, EU has started lagging behind, because in January 2006, only four nations are 100 percent efficient, while all other nations are lagging behind in economic performance. The study also shows the areas in which inefficient member nations are lagging behind and how they can improve their performance to bring them at par with other participating nations.

We used data envelopment analysis to benchmark EU 15 nations. The data envelopment analysis is a powerful technique for performance measurement. The major strength of DEA is its objectivity. DEA identifies efficiency ratings based on numeric data as opposed to subjective human judgment and opinion. In addition, DEA can handle multiple input and outputs measured in different units. Also, unlike statistical methods of performance analysis, DEA is non-parametric, and does not assume a functional form relating inputs and outputs.

However, as with any other study, this study using DEA has certain limitations (Ramanathan, 2003). The application of DEA involves solving a separate linear program for each DMU. Thus, the use of DEA can be computationally intensive. In addition, as DMU is an extreme point technique, errors in measurement can cause significant problems. DEA efficiencies are very sensitive to even small errors, thus making sensitivity analysis an important component of post-DEA procedure. Also, as DEA is a non-parametric technique, statistical hypothesis tests are difficult to apply. Therefore, further extension of this study would be to perform principal component analysis of the all the DEA model combinations. Furthermore, we can also use logistic regression to test the validity of the results.

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Table 2: DEA Efficiency Scores for the EU states (1993-2006)

Country	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
AUSTRIA	100%	92%	100%	96%	96%	100%	99%	95%	94%	88%	100%	89%	81%	96%
BELGIUM	100%	100%	100%	100%	100%	100%	100%	88%	84%	89%	100%	100%	76%	75%
DENMARK	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
FINLAND	79%	100%	100%	100%	100%	100%	100%	100%	100%	100%	76%	100%	100%	100%
FRANCE	81%	100%	84%	77%	100%	100%	100%	100%	100%	100%	100%	87%	75%	74%
GERMANY	100%	92%	93%	88%	85%	95%	87%	88%	98%	100%	100%	100%	88%	89%
GREECE	45%	41%	84%	100%	100%	100%	100%	100%	100%	100%	37%	100%	100%	76%
IRELAND	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
ITALY	72%	68%	80%	100%	100%	100%	87%	76%	79%	90%	94%	87%	87%	61%
NETHERLANDS	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	87%	91%	81%
PORTUGAL	100%	100%	100%	100%	100%	95%	55%	63%	71%	55%	100%	93%	88%	36%
SPAIN	100%	93%	86%	65%	100%	100%	100%	68%	82%	90%	100%	87%	81%	69%
SWEDEN	91%	100%	100%	100%	100%	100%	100%	100%	100%	92%	100%	100%	100%	100%
UNITED KINGDOM	100%	78%	62%	65%	100%	100%	100%	100%	100%	100%	65%	81%	100%	100%

Table 3: Efficiency Score and Ranking for 1993

Country	1993	Rank
SPAIN	100%	1
PORTUGAL	100%	1
IRELAND	100%	1
DENMARK	100%	1
BELGIUM	100%	1
GERMANY	100%	1
AUSTRIA	100%	1
UNITED KINGDOM	100%	1
NETHERLANDS	100%	1
SWEDEN	91%	2
FRANCE	81%	3
FINLAND	79%	4
ITALY	72%	5
GREECE	45%	6

Table 4: Efficiency Score and Ranking for 2006

Country	2006	Rank
UNITED KINGDOM	100%	1
SWEDEN	100%	1
DENMARK	100%	1
IRELAND	100%	1
FINLAND	100%	1
AUSTRIA	96%	2
GERMANY	89%	3
NETHERLANDS	81%	4
GREECE	76%	5
BELGIUM	75%	6
FRANCE	74%	7
SPAIN	69%	8
ITALY	61%	9
PORTUGAL	36%	10

Table 5: Peer Countries and their weights

Country	efficiency	DENMARK	FINLAND	IRELAND	SWEDEN
AUSTRIA	1.0413	78%	0%	22%	0%
BELGIUM	1.332467	92%	0%	0%	8%
FRANCE	1.351275	89%	0%	11%	0%
GERMANY	1.120257	8%	69%	0%	23%
GREECE	1.320281	1%	0%	99%	0%
ITALY	1.626545	46%	0%	54%	0%
NETHERLANDS	1.229615	51%	8%	0%	41%
PORTUGAL	2.784657	86%	0%	14%	0%
SPAIN	1.443469	14%	0%	86%	0%

Table 6: Benchmarking Factor and Hit Rate for Pareto Efficient Countries

Country	Benchmarking Factor	Percentage rate
Denmark	9	100%
Finland	2	22%
Ireland	6	67%
Sweden	3	33%

Table 7: Slack Variables for Inefficient Countries (2006)

Country	efficiency	Inflation	current account as %age of XGS	Exchange Rate Stability	Current Account as a %age of GDP	GDP per head of population	International Liquidity	Real GDP Growth
AUSTRIA	1.0413	0.0000	4.4442	0.1342	2.3429	0.0000	3.7101	0.7063
BELGIUM	1.332467	0.7497	2.7239	2.3027	0.0000	0.0000	4.9774	0.3427
FRANCE	1.351275	0.0000	6.0122	2.8597	2.8867	0.0000	3.0455	0.5175
GERMANY	1.120257	0.5515	0.0000	0.0000	0.1023	0.0000	1.5004	0.9243
GREECE	1.320281	1.1045	25.4027	2.8490	7.8314	21385.0663	0.0000	0.0000
ITALY	1.626545	0.0163	6.4999	5.4375	2.3456	0.0000	0.0000	3.1570
NETHERLANDS	1.229615	0.1963	2.7968	0.0000	0.0000	0.0000	3.3795	1.9404
PORTUGAL	2.784657	0.5700	57.8058	15.6268	24.6500	0.0000	0.0000	0.6686
SPAIN	1.443469	0.7284	24.0336	3.9041	7.2498	10947.7179	0.0000	0.0000

Figure 1: Trends of the 15 EU nations from 1993 to 2006.