Digital Readiness and Economic Growth: Analyzing the Impact of DESI Scores on GDP in European Countries

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ABSTRACT: This study investigates the impact of the Digital Economy and Society Index (DESI) on Gross Domestic Product (GDP) across European countries, incorporating control variables such as Industrial Production, Employment, Inflation, and Investment. The research employs panel regression analysis of data from 22 European nations from 2017 to 2022, focusing on DESI components like Human Capital, Connectivity, Integration of Digital Technology, and Digital Public Services. The study's findings reveal significant correlations, with specific emphasis on the positive influence of Human Capital and Integration of Digital Technology on GDP, while showing an unexpected negative correlation with Digital Public Services. This research contributes to the understanding of the complex relationship between digital readiness and economic performance, offering valuable insights for policy development and economic planning in the era of digital transformation.

INTRODUCTION
The Digital Economy and Society Index (DESI) stands as a comprehensive composite metric developed by the European Commission, designed to assess, and benchmark the level of digital competencies and the evolution of digital infrastructure within the member states of the European Union. Recognized for its intricate and multifaceted nature, DESI serves as a barometer for gauging digital readiness and provides a critical indicator for examining the digital landscape within European nations.

In this research, a meticulous investigation has been undertaken to explore the complex relationship between economic growth and DESI Scores. The study acknowledges the pivotal role of DESI Scores as comprehensive indicators for assessing the extent of digital integration in society and their potential influence on the economic advancement of a nation. This exploration is of paramount importance for providing in-depth insights into how digital preparedness interplays with economic development, offering invaluable guidance for policymakers and economists. It contributes to an enriched understanding of the dynamics that govern the impact of digitalization on economic development within the European context.

To enhance the robustness of this exploration, the study employs control variables including Industrial Production, Employment, Inflation, and Investment:

Industrial Production: Recognized as a traditional economic driver, industrial production is considered a reflection of a nation's manufacturing and production capabilities. Within the framework of this study, it serves to elucidate the relationship between a country's industrial base and its digital evolution as measured by DESI.

Employment: The employment rate is included as a control variable to factor in the labor market dynamics and their correlation with digital progress. Employment levels are indicative of the economic health of a nation and can significantly influence and be influenced by digital transformation initiatives.

Inflation: As an economic indicator, inflation is incorporated to account for the changes in price levels which can impact purchasing power and investment in digital infrastructure. The control of inflation within the analysis helps in understanding the economic environment in which digital competencies are fostered.

Investment: Investment, particularly in technology and infrastructure, is pivotal for digital growth. By including investment as a control variable, the study aims to capture the extent to which capital allocation in digital assets correlates with the overall DESI performance.

The inclusion of these control variables is based on their established significance in economic literature and their potential to influence digital readiness and growth. By accounting for these additional economic factors, the study ensures a comprehensive analysis of the variables that may affect or be affected by the digitalization measured by DESI, providing a more nuanced view of the digital economy’s interconnection with broader economic indicators.
HUMAN CAPITAL
Human Capital, a critical component of the Digital Economy and Society Index (DESI), pertains to the skills and competencies necessary to thrive in the digital era. This dimension evaluates the level of digital literacy and the availability of advanced digital skills among the workforce and the general population. The development of human capital in the digital domain is pivotal for driving innovation and economic growth in a technology-driven world. Van Laar et al. (2017) emphasize the growing need for digital skills, correlating them with enhanced employability and productivity in the digital economy. This aspect of DESI underscores the importance of education and training in equipping individuals with the necessary digital skills.

CONNECTIVITY
Connectivity, as featured in DESI, assesses the extent and quality of broadband infrastructure, crucial for enabling access to digital services and technologies. This facet reflects the foundational role of connectivity in facilitating digital engagement and inclusion. The European Commission’s report on digital progress (European Commission, 2021) highlights the importance of high-speed internet as a key driver for digital transformation. Mattelart (2014) discusses how connectivity not only bridges geographical distances but also integrates diverse communities into the global digital landscape, making it a cornerstone of digital development.

INTEGRATION OF DIGITAL TECHNOLOGY
The Integration of Digital Technology in DESI measures how businesses and organizations assimilate digital technologies into their processes and services. This component is indicative of the degree to which industries and services are evolving to incorporate digital innovations. The European Commission (2021) notes the significance of technology integration in enhancing competitiveness and operational efficiency. Bughin et al. (2017) explore the transformative impact of digital technologies in business models, emphasizing their role in creating new value-creation opportunities and driving economic growth.

DIGITAL PUBLIC SERVICES
Digital Public Services, another crucial element of DESI, evaluates the digitalization of government services and the public sector’s interaction with citizens and businesses. This dimension reflects the effectiveness and efficiency of digital governance. The European Commission (2021) recognizes the critical role of digital public services in improving accessibility, transparency, and citizen engagement. Wirtz and Daiser (2017) discuss the evolution of e-government services, highlighting how digitalization in the public sector can lead to more effective service delivery and enhanced public value. These components of the DESI index collectively provide a comprehensive view of a nation's digital landscape, underlining the multifaceted nature of digital development. Each element plays a distinct yet interconnected role in assessing the overall digital readiness and capacity of EU member states.

METHODOLOGY
Regression analysis constitutes a fundamental statistical approach for modeling the association between a dependent variable and one or more explanatory variables. This analytical method aims to discern the manner in which the expected value of the dependent variable shifts in response to changes in the explanatory variables. Linear regression, the most rudimentary form of regression, posits this relationship as a linear function. The origins of regression analysis can be traced back to the seminal work of Sir Francis Galton during the late 19th century, from which it has developed into a cornerstone technique within the realms of statistical inference and econometrics (Stigler, 1986).

EVOLUTION TO PANEL REGRESSION
While traditional regression analysis provides insights, its scope is limited to cross-sectional or time-series data. Cross-sectional regression analyzes data collected at a single point in time across various subjects, whereas time-series regression deals with data collected over time for a single entity. Panel regression, or longitudinal data analysis, emerges as a hybrid approach combining elements of both cross-sectional and time-series data. This methodology allows researchers to analyze data that vary across entities (e.g., individuals, companies, countries) and over time, providing a more nuanced understanding of dynamic relationships.

THEORETICAL FOUNDATIONS OF PANEL REGRESSION
Panel regression models can be divided into two primary types: fixed effects models and random effects models. The choice between these models depends on the nature of the unobserved heterogeneity across entities.

1. **Fixed Effects Models**: These models assume that individual-specific effects are unique and correlate with independent variables. They control time-invariant characteristics, isolating the net effect of predictors on the response variable. This approach was notably advanced by Mundlak (1978), who emphasized its importance in the presence of unobserved individual heterogeneity.
2. **Random Effects Models:** Proposed by Wallace and Hussain (1969), these models treat individual-specific effects as random and uncorrelated with the regressors. This assumption allows for more generalizability and efficiency under certain conditions.

3. **Clustered standard errors:** Essential technique in panel data econometrics for addressing issues of heteroskedasticity and autocorrelation. Pioneered by Arellano (1987), this approach provides robust standard error calculations that are critical for data with intragroup correlations. Froot (1989) expanded upon this to encompass cross-sectional dependence, a vital concern in financial econometrics. Rogers (1993) further refined the methodology, highlighting its importance across various applications where sample clustering occurs. These methods are crucial when data violate standard econometric assumptions, often detected by diagnostic tests like those developed by Breusch and Pagan (1979), and Durbin and Watson (1950).

### DIAGONOSTICS OF THE DATASET

<table>
<thead>
<tr>
<th>Test</th>
<th>LM-Stat</th>
<th>LM p-value</th>
<th>F-Stat</th>
<th>F p-value</th>
<th>Durbin-Watson</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Test</td>
<td>115.5846</td>
<td>&lt; 0.0000001</td>
<td>13.9224</td>
<td>&lt; 0.0000001</td>
<td>N/A</td>
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<td>Breusch-Pagan</td>
<td>57.7610</td>
<td>&lt; 0.0000001</td>
<td>11.9624</td>
<td>&lt; 0.0000001</td>
<td>N/A</td>
</tr>
<tr>
<td>Durbin-Watson</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>0.4761</td>
</tr>
</tbody>
</table>

**Interpretation of Results:**

- **White Test:** The White test indicates the presence of heteroskedasticity, as suggested by a highly significant LM statistic and p-value. The F-statistic and its associated p-value further confirm this result, with both indicating strong evidence against the null hypothesis of homoskedasticity.
- **Breusch-Pagan Test:** Similarly, the Breusch-Pagan test provides evidence of heteroskedasticity with a significant LM statistic and p-value. The F-statistic and its corresponding p-value also reject the null hypothesis of homoscedastic errors.
- **Durbin-Watson Test:** The Durbin-Watson statistic of 0.4761 suggests positive autocorrelation in the residuals of the regression model. This is below the commonly used threshold of approximately 2, which indicates no autocorrelation.

These results would suggest that the appropriate econometric approach would involve correcting for heteroskedasticity and possibly addressing autocorrelation within the model. Therefore, I will be employing Random Effect Model with Clustered standard errors to address heteroskedasticity and autocorrelation.

### LITERATURE REVIEW

#### Industrial Production and GDP:

1. **The Role of Industrial Production in Economic Growth:**
   - Herrendorf, B., Rogerson, R., & Valentinyi, Á. (2013). "Two Perspectives on Preferences and Structural Transformation." *American Economic Review*. This study discusses the role of industrial production in structural transformation and economic growth, emphasizing its impact on GDP.
2. **Industrial Production as an Indicator of Economic Performance:**

#### Employment and GDP:

1. **Employment as a Driver of Economic Growth:**
2. **Labor Market Conditions and GDP Dynamics:**

#### Inflation and GDP:

1. **Inflation’s Impact on Economic Activity:**
2. **Understanding the Inflation-Growth Nexus:**
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**Investments and GDP:**
1. Investment as a Determinant of Economic Growth:

2. Capital Formation and Economic Performance:

**DESI and Economy:**
1. Economic Impact of Digital Technologies:

2. The relationship between digitalization and economic growth:

**DATA**
This study utilizes a dataset spanning the years 2017 to 2022, encompassing DESI scores for 22 European countries: Austria, Belgium, Czechia, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Luxembourg, Netherlands, Poland, Portugal, Slovakia, Slovenia, Spain, and Sweden. The dataset includes nine key variables: Human Capital, Connectivity, Integration Technology, Digital Public Services, Industrial Production, Employment, Inflation, Investment, and GDP, resulting in a total of 1,452 data points. This comprehensive dataset empowers an in-depth analysis of the relationship between digital readiness and economic indicators across these European nations over time.

**DESCRIPTIVES**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Count</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>Max</th>
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<tbody>
<tr>
<td>Human Capital</td>
<td>132</td>
<td>1.06</td>
<td>0.08</td>
<td>0.91</td>
<td>1.00</td>
<td>1.05</td>
<td>1.13</td>
<td>1.25</td>
</tr>
<tr>
<td>Connectivity</td>
<td>132</td>
<td>0.96</td>
<td>0.15</td>
<td>0.50</td>
<td>0.86</td>
<td>0.96</td>
<td>1.06</td>
<td>1.28</td>
</tr>
<tr>
<td>Integration T.</td>
<td>132</td>
<td>0.86</td>
<td>0.14</td>
<td>0.50</td>
<td>0.77</td>
<td>0.88</td>
<td>0.95</td>
<td>1.17</td>
</tr>
<tr>
<td>Digital Public S.</td>
<td>132</td>
<td>1.16</td>
<td>0.11</td>
<td>0.78</td>
<td>1.10</td>
<td>1.18</td>
<td>1.24</td>
<td>1.36</td>
</tr>
<tr>
<td>Industrial Prod.</td>
<td>132</td>
<td>2.05</td>
<td>0.05</td>
<td>1.95</td>
<td>2.02</td>
<td>2.04</td>
<td>2.07</td>
<td>2.26</td>
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<tr>
<td>Employment</td>
<td>132</td>
<td>1.84</td>
<td>0.04</td>
<td>1.73</td>
<td>1.83</td>
<td>1.85</td>
<td>1.87</td>
<td>1.91</td>
</tr>
<tr>
<td>Inflation</td>
<td>132</td>
<td>2.03</td>
<td>0.03</td>
<td>2.00</td>
<td>2.01</td>
<td>2.02</td>
<td>2.05</td>
<td>2.14</td>
</tr>
<tr>
<td>Investment</td>
<td>132</td>
<td>5.05</td>
<td>0.56</td>
<td>4.06</td>
<td>4.61</td>
<td>5.09</td>
<td>5.39</td>
<td>6.07</td>
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<tr>
<td>GDP</td>
<td>132</td>
<td>5.64</td>
<td>0.55</td>
<td>4.65</td>
<td>5.26</td>
<td>5.62</td>
<td>6.02</td>
<td>6.73</td>
</tr>
</tbody>
</table>

The dataset's summary statistics, based on 132 observations for each variable, show average values ranging from 0.86 to 5.64, with standard deviations from 0.03 to 0.56, reflecting varying degrees of dispersion among the variables. The data spans across a spectrum of minimum and maximum values indicative of each variable's scale, with the least spread observed in Inflation and the greatest in Investment. This variability suggests a diverse set of characteristics within the measured indicators of economic performance and digital integration.

**PANEL REGRESSION RESULTS:**

<table>
<thead>
<tr>
<th>Parameter Estimates</th>
<th>Parameter</th>
<th>Std. Err.</th>
<th>T-stat</th>
<th>P-value</th>
<th>Lower CI</th>
<th>Upper CI</th>
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</thead>
<tbody>
<tr>
<td>const</td>
<td>1.9304</td>
<td>0.4570</td>
<td>4.2236</td>
<td>0.0000</td>
<td>1.0257</td>
<td>2.8350</td>
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<tr>
<td>HumanCap</td>
<td>0.3164</td>
<td>0.1390</td>
<td>2.2759</td>
<td>0.0246</td>
<td>0.0412</td>
<td>0.5916</td>
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<td>Connectivity</td>
<td>0.0194</td>
<td>0.0319</td>
<td>0.6065</td>
<td>0.5453</td>
<td>-0.0439</td>
<td>0.0826</td>
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<tr>
<td>IntegrationTech</td>
<td>0.2250</td>
<td>0.0751</td>
<td>2.9969</td>
<td>0.0033</td>
<td>0.0764</td>
<td>0.3735</td>
</tr>
</tbody>
</table>
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<table>
<thead>
<tr>
<th>Parameter Estimates</th>
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<th>Std. Err.</th>
<th>T-stat</th>
<th>P-value</th>
<th>Lower CI</th>
<th>Upper CI</th>
</tr>
</thead>
<tbody>
<tr>
<td>DigitalPublicS</td>
<td>-0.1678</td>
<td>0.0838</td>
<td>-2.0019</td>
<td>0.0475</td>
<td>-0.3338</td>
<td>-0.0019</td>
</tr>
<tr>
<td>IndustrialProd</td>
<td>0.4257</td>
<td>0.0781</td>
<td>5.4503</td>
<td>0.0000</td>
<td>0.2711</td>
<td>0.5804</td>
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<tr>
<td>Employment</td>
<td>0.6514</td>
<td>0.2427</td>
<td>2.6838</td>
<td>0.0083</td>
<td>0.1709</td>
<td>1.1318</td>
</tr>
<tr>
<td>Inflation</td>
<td>0.2671</td>
<td>0.0963</td>
<td>2.7727</td>
<td>0.0064</td>
<td>0.0764</td>
<td>0.4577</td>
</tr>
<tr>
<td>Investment</td>
<td>0.1463</td>
<td>0.0777</td>
<td>1.8840</td>
<td>0.0619</td>
<td>-0.0074</td>
<td>0.3001</td>
</tr>
</tbody>
</table>

- **Constant (1.9304):** This constant term indicates the expected level of GDP when all the independent variables are held at zero. It provides a baseline for comparisons when assessing the impact of the variables.
- **HumanCap (0.3164):** A 1% increase in Human Capital is associated with a 0.3164% increase in GDP. This suggests that investments in human capital are positively correlated with economic growth, which could be due to the enhanced productivity and innovation that better educated, or more skilled workers bring to the economy.
- **Connectivity (0.0194):** The Connectivity variable, while positive, is not statistically significant, implying that within this model, increases in connectivity measures do not have a discernible impact on GDP. This might indicate that other factors not captured by this variable are more influential in GDP outcomes.
- **IntegrationTech (0.2250):** A 1% increase in Integration Technology corresponds to a 0.2250% increase in GDP. This positive relationship suggests that technology integration within industries or services positively affects economic output, possibly by increasing efficiency and competitiveness.
- **DigitalPublicS (-0.1678):** An increase in Digital Public Services is associated with a decrease in GDP of 0.1678%. This counterintuitive result could suggest that investments in digital public services may not immediately translate into economic growth or might be reflecting short-term costs without immediate economic benefits.
- **IndustrialProd (0.4257):** The Industrial Production variable shows a strong positive impact on GDP, with a 1% increase in industrial production associated with a 0.4257% increase in GDP. This underlines the traditional role of industrial production as a driver of economic growth.
- **Employment (0.6514):** A 1% increase in Employment is associated with a 0.6514% increase in GDP, indicating a strong positive relationship. This could be due to the direct impact of higher employment on consumption and production within the economy.
- **Inflation (0.2671):** The positive coefficient for Inflation suggests that a 1% increase in inflation is associated with a 0.2671% increase in GDP. This could reflect the short-term boost that inflation sometimes gives to economic activity before any central bank countermeasures.
- **Investment (0.1463):** The coefficient for Investment is positive, suggesting that a 1% increase in investment is associated with a 0.1463% increase in GDP. While this is not statistically significant at the 5% level, it does indicate a trend where investment is likely to be beneficial for economic growth.

**R-Squared Values Interpretation:**
- **Overall R-squared (0.9039):** The high overall R-squared value suggests that the model explains a substantial portion of the variation in GDP across both entities and time.
- However, since the 'Between' R-squared is much lower, it indicates that the model is more effective at explaining the variation within entities over time rather than differences between them.

**CONCLUSION**

In concluding my study on the Digital Economy and Society Index (DESI), developed by the European Commission, I focused on its crucial role in assessing digital preparedness among EU member states. DESI serves as a key tool to evaluate the integration of digital technologies into various societal sectors and its economic impact. It acts as a vital indicator of digital progress, essential for policymakers, economists, and stakeholders.

My research aimed to explore the relationship between economic growth and DESI Scores, acknowledging these scores as integral in assessing Europe’s digital landscape. Additionally, I incorporated control variables based on their relevance in existing literature, ensuring a thorough analysis.

Through panel regression modeling, I examined the dynamic interplay between digital readiness, as indicated by DESI scores, and various economic indicators. My findings revealed significant insights into GDP determinants in the context of digitalization. Critical variables impacting GDP included Human Capital, Integration Technology, Industrial Production, Employment, Inflation, and Investment.

Human Capital (0.32): Demonstrated a positive influence on GDP, suggesting that investments in human capital significantly contribute to economic growth.
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Integration Technology (0.23): Highlighted the importance of technological integration in driving economic performance.
Industrial Production (0.43): Showed a strong positive effect on GDP, underlining the traditional role of industrial output in economic expansion.
Employment (0.65): Indicated a substantial positive impact on GDP, emphasizing the importance of job creation in economic development.
Inflation (0.27): Its positive relationship with GDP suggested that moderate inflation could be associated with economic growth.
Investment (0.15): Although less pronounced, indicated a trend where increased investment is likely to benefit economic growth. It's crucial to understand that while digitalization is a significant factor in economic development, it forms part of a complex ecosystem. The lower R-squared values for Between and Overall suggest the influence of other variables on GDP across different entities. However, the high R-squared Within value indicates the model's effectiveness in capturing GDP changes over time within each entity.

REFERENCES

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