The Role of Technological Progress in Social Development:
Evidence from Europe in the Light of Sustainable Development Goals

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Keywords: Technological progress; Social sustainability; Sustainable development goals; Sustainable development indicators; R&D investments

Abstract: This study aims to analyze the relationships between two variables associated with the growth of modern economies: technological progress and social development. The research intends to test these relations within the framework of the Sustainable Development Goals set by the UN in 2015 in order to achieve the preservation of the planet, the welfare of the population, peace and prosperity. To this end, the research analyzes the correlations, within the European Union, between technological progress and social development in the period 2015-2021, that is from the year in which the 2030 Agenda for Sustainable Development was adopted by the United Nations Member States to today. The variables representative of technological progress are drawn from the indicators belonging to Goal 9 - Industry, Innovation and Infrastructure, while for social development the study referred to the indicators of Goal 8 - Decent Work and Economic Growth. The results show that, although the two phenomena are positively correlated, not all connections are equally strong.

1. INTRODUCTION

This study aims to analyze the impact of technological progress on social sustainability, starting from the observation that the two aspects examined represent respectively the most powerful strengths and weaknesses in this historical moment. The relationship between technological progress and social sustainability is a complex phenomenon and not necessarily unambiguous. On the one hand, technological development creates or should create, the premises for an improvement in human well-being. On the other hand, however, it is also capable of causing distortions of competition and markets – especially of work – which conflict with the expected common good.

In order to analyze the relationship between technological development and social sustainability, the study selected the significant variables in the context of the Sustainable Development Goals (SDGs) set out in the 2030 Agenda by United Nations (UN) member states. The 2030 Agenda for Sustainable Development represents a common project for peace and prosperity for people and the planet, now and in the future. It is based on 17 Sustainable Development Goals (SDGs), which require action by all countries – developed and developing – in a global partnership (Avtar et al., 2020). The goal of ending poverty and its serious consequences must be pursued together with strategies for improving health and education, eliminating inequalities and stimulating economic growth. This process must also look at climate change and act to ensure that our oceans and forests are preserved.

The results of the survey for the period 2015-2021 show that, although investment in R&D has substantially increased, not all the variables on which technological progress should have had a positive influence improved in all years of the period under consideration. While, in general,
the study shows that there are mostly positive relationships between technological innovation and social progress, some indicators of sustainable development show to be more sensitive than others in reacting to the growth of R&D investments. This suggests the presence of leeway on which it is still possible to intervene to make the social improvements associated with progress more powerful.

This study helps to deepen the research line concerning the existing relationships between the SDGs. Its originality lies in the use of sustainable development indicators to identify the dominant relationship – positive or negative – between technological innovation and collective well-being.

The research has both theoretical and practical implications. From a theoretical point of view, it contributes to the literature that aims to investigate the multiple implications of progress and the contrasting effects that it can have on society. From a practical point of view, the usefulness of the study lies in providing trend signals helpful for understanding in depth the contribution that innovation – if managed according to sustainability criteria – can give to humanity’s progress.

2. LITERATURE REVIEW AND HYPOTHESIS FORMULATION

Relations between SDGs play a crucial role in achieving sustainable economic growth. First of all, only 7 years are left before the deadline set by the 2030 Agenda, and the complexity of the program requires a considerable time frame. Secondly, the greater the synergies between the 17 goals, the faster they can be achieved. On the contrary, trade-offs or opposing goals make the simultaneous implementation of all targets more difficult and slower.

In this regard, the study of Kuc-Czarnecka et al. (2023) showed that the synergies between the SDGs are greater than the trade-offs, which are found in only one case, i.e. the negative correlation of Goal 15 - Life on Land with Goal 3 - Good Health and Well-Being and Goal 17- Partnerships for the Goals, while Goal 7 - Affordable and Clean energy does not correlate with others.

Other studies have analyzed SDGs’ relationships with factors external to them, such as the food supply chain (Chandan et al., 2023), industry 4.0 technologies (Bai et al., 2023), local cultural factors (Ordonez-Ponce, 2023), SDGs engagement intensity and gender board diversity (Gutiérrez-Fernández et al., 2023), core competence and core resources (Hsu, 2023), climate change disclosure (Toukabri & Mohamed Youssef, 2023), ESG factors and economic growth (Sadiq et al., 2023).

However, as highlighted by Allen et al. (2018), while some progress has been made in planning the implementation of SDGs, key gaps remain in the assessment of the interconnections, trade-offs and synergies between goals. This study aims to contribute to the reduction of these gaps through the highlighting of relationships that can be useful to policymakers to make the achievement of targets more effective.

The relationships between technologies and social development are far from secondary, as shown by Palomares et al. (2021), who highlight the role of artificial intelligence and other digital technologies with respect to human economic, technological, social and environmental needs. These relations reveal the wide potential of digital technologies, which, thanks to the ability to process a large amount of data, can help to improve the flow of information between the actors involved in achieving the SDGs. On the contrary, considered in terms of the quality of working
conditions, artificial intelligence causes an effect opposite to Goal 8 because it degrades the nature of decent work (Braganza et al., 2021).

A further positive impact on the SDGs generated by technological development, and in particular by innovation, as well as by the structural transformation of the economy, is achieved through the improvement of energy efficiency, as shown by Chen et al. (2021) for the MENA (Middle East and North Africa) countries. Technological innovation not only facilitates the transition to the use of renewable energy but also improves production processes by reducing energy intensity. However, despite the presence of positive interconnections between the 17 Goals, some critical issues make it essential to use a comprehensive approach, able to simultaneously consider all targets and intercept not only their mutual strengthening but also their possible conflicts (Fu et al., 2019).

Since technological innovation is at the heart of progress in renewable energy, it also promotes the achievement of climate goals, especially in countries with high pollution potential, such as China, at the forefront of global carbon emissions (Xing et al., 2023).

Economic growth and industrialization, which in modern economies are fuelled by technological development, may, however, conflict with the goals of environmental sustainability. This is the case of the Next 11 countries which, while showing continued growth and progressive industrialization, could follow an unsustainable development trajectory in nature (Sinha et al., 2020).

A similar potential conflict exists between the development of certain technologies and the SDGs. One example is Carbon Capture and Utilization (CCU) applications, which have both positive and negative indirect effects, such as strengthening the competitive advantage of developed countries over developing countries (Olfe-Kräutlein, 2020).

Moreover, the impact of technological innovation on sustainability goals, although positive, differs depending on the stage reached by economic development and the level of income of the countries involved. Technological innovation tends to be effective only in the richest countries, while its impact is almost absent in low-income countries (Omri, 2020).

At the same time, it is also necessary to recall some advantages of developing countries in achieving sustainable goals. Indeed, among developing countries, those in an early stage of industrialization are capable of achieving economic and industrial growth with limited environmental consequences. A further competitive advantage of developing countries is their ability to provide labor at below-average costs, increasing employment opportunities in labor-intensive sectors such as food and drink, chemicals, textiles and clothing (Kynčlová et al., 2020).

Although the literature acknowledges the presence of significant connections between the SDGs, studies analyzing them using indicators associated with these goals are not yet particularly widespread. Among these studies is that by Kenny and Patel (2017) examining the relationship between GDP per capita and some key development indicators as “Technological gains”. These relationships are positive and explain why the major performers are significantly above average at a given income level. However, for the targets set by the SDGs to be reached technological progress must be present rapidly along the path of economic growth.

Goal 9, and specifically industrial innovation, is also used in the literature to analyze other effects, such as those exerted on sustainable urban development. In particular, the study of Gao
et al. (2022) analyzes how sustainable urbanization affects the protection of intellectual property and considers its consequences in terms of economic growth, technological progress and strengthening of social welfare.

The simultaneous presence of both positive and negative relations between technological progress and social development is noted by Ioannides et al. (2021), who emphasize how digital transformations, although useful to improve labor flexibility, can lead to further aggravation of the already existing hyper-exploitation in labor relations.

Overall, literature has highlighted the existence of multiple, and sometimes discordant, relationships between different goals. This study aims to contribute to research on this topic, by reconstructing some significant trends useful in understanding the phenomenon.

To this end, the study formulated the following research hypotheses:

**H1.** Technological progress has a positive impact on the average standard of living of the population.

**H2.** Technological progress has a positive impact on economic growth.

**H3.** Technological progress has a positive impact on employment.

### 3. METHODOLOGY

#### 3.1. Variable Selection

In this research, the relations between technological progress and social development are observed through the analysis of Goal 9 - Industry, Innovation and Infrastructure and Goal 8 - Decent Work and Economic Growth, as defined by the 2030 Agenda. Specifically, the study examines technological progress using three of the nine indicators associated with Goal 9: (a) gross domestic expenditure on R&D; (b) R&D personnel; and (c) patent applications. As indicators of social development, the study considered three of the ten indicators related to Goal 8: (a) real GDP per capita; (b) investment share of GDP by institutional sectors; (c) young people neither in employment nor in education and training. The geopolitical context of reference is the European Union and the analysis covers the seven years 2015-2021, which was considered sufficiently extensive to identify significant trends.

<table>
<thead>
<tr>
<th>Eurostat definition of the variable</th>
<th>Symbol in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross domestic expenditure on R&amp;D - Gross domestic expenditure on R&amp;D (GERD) as a percentage of the gross domestic product (GDP). (Eurostat).</td>
<td>R&amp;D_Exp</td>
</tr>
<tr>
<td>R&amp;D personnel - The share of R&amp;D personnel broken down by the following institutional sectors: business enterprise (BES), government (GOV), higher education (HES), private nonprofit (PNP). Data are presented as a share of the economically active population. (Eurostat).</td>
<td>R&amp;D_Pers</td>
</tr>
<tr>
<td>Patent applications - The number of requests for patent protection of an invention filed with the European Patent Office (EPO). (Eurostat).</td>
<td>PATENT_App</td>
</tr>
<tr>
<td>Real GDP per capita - The ratio of real GDP to the average population of a specific year. (Eurostat).</td>
<td>GDP_Per capita</td>
</tr>
<tr>
<td>Investment share of GDP by institutional sectors - The share of GDP that is used for gross investment (rather than being used for e.g. consumption or exports). (Eurostat).</td>
<td>GDP_Inv</td>
</tr>
<tr>
<td>Young people neither in employment nor education and training - The share of the population aged 15 to 29 who is not employed and not involved in education or training. (Eurostat).</td>
<td>UNEMPLOYED_Young</td>
</tr>
</tbody>
</table>

Source: Eurostat
The variables are taken from the Eurostat database and the data was processed through the software Statplus 7. Table 1 shows the definition of variables according to Eurostat and the symbols by which they were identified in this study.

The variables representing technological progress are R&D_Exp, R&D_Pers and PATENT_App and have been taken over by the study as independent variables. The variables representing social development are GDP_Per capita, GDP_Inv and EMPLOYED_Young and have been assumed as dependent variables.

3.2. Empirical models

The study used the following multiple regression models to test the hypotheses.

For H1 model 1 is as follows:

$$GDP_{\text{Per capita}} = \beta_0 + \beta_1 * \text{R&D}_\text{Exp} + \beta_2 * \text{R&D}_\text{Pers} + \beta_3 * \text{PATENT}_\text{App} + \varepsilon$$

GDP_Per capita expresses the average standard of living of the population at time $t$ and is a function of Gross domestic expenditure on R&D ($\text{R&D}_\text{Exp}$), the share of R&D personnel ($\text{R&D}_\text{Pers}$) and patent applications ($\text{PATENT}_\text{App}$).

For H2 model 2 is as follows:

$$GDP_{\text{Inv}} = \beta_0 + \beta_1 * \text{R&D}_\text{Exp} + \beta_2 * \text{R&D}_\text{Pers} + \beta_3 * \text{PATENT}_\text{App} + \varepsilon$$

Model 2 uses the same independent variables as model 1 but considers economic growth as an indicator of population well-being and assumes it as a dependent variable expressed as a share of GDP for gross investment ($\text{GDP}_\text{Inv}$).

For H3 model 3 is as follows:

$$\text{UNEMPLOYED}_\text{Young} = \beta_0 + \beta_1 * \text{R&D}_\text{Exp} + \beta_2 * \text{R&D}_\text{Pers} + \beta_3 * \text{PATENT}_\text{App} + \varepsilon$$

Model 3 considers the unemployment indicator ($\text{UNEMPLOYED}_\text{Young}$) as a variable dependent on technological progress.

4. RESULTS AND DISCUSSION

4.1. Descriptive Statistics and Correlation Analysis

Table 2 presents the main statistical results – minimum, maximum, mean and standard deviation – referred to all variables. The trend of the selected variables in the observation period is shown in Table 3. As Table 3 shows, over the period observed, all indicators of technological progress and social sustainability increased almost continuously, while the unemployment indicator of the young population decreased. This first observation confirms the presence of a positive relationship between progress and social sustainability. However, not all relationships are equally strong, as the correlation analysis below shows. Table 4 presents Pearson correlation coefficients for all variables.
Table 2. Descriptive statistics

<table>
<thead>
<tr>
<th>Variable</th>
<th>Min</th>
<th>Max</th>
<th>Mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D Exp</td>
<td>2.14</td>
<td>2.34</td>
<td>2.2257</td>
<td>0.0781</td>
</tr>
<tr>
<td>R&amp;D Pers</td>
<td>1.3046</td>
<td>1.5903</td>
<td>1.4431</td>
<td>0.1041</td>
</tr>
<tr>
<td>PATENT_App</td>
<td>139.4</td>
<td>151.75</td>
<td>145.6771</td>
<td>4.5248</td>
</tr>
<tr>
<td>GDP_Per capita</td>
<td>29,280</td>
<td>31,300</td>
<td>30,271</td>
<td>819.8461</td>
</tr>
<tr>
<td>GDP_Inv</td>
<td>20.13</td>
<td>22.39</td>
<td>21.3443</td>
<td>0.9194</td>
</tr>
<tr>
<td>UNEMPLOYED_Young</td>
<td>12.8</td>
<td>15.3</td>
<td>13.8571</td>
<td>0.8979</td>
</tr>
</tbody>
</table>

Source: Author

Table 3. Trend of the variables in Euro area - 19 countries (2015-2021)

<table>
<thead>
<tr>
<th></th>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross domestic expenditure on R&amp;D (Percentage of GDP)</td>
<td>2.14</td>
<td>2.14</td>
<td>2.18</td>
<td>2.22</td>
<td>2.26</td>
<td>2.34</td>
<td>2.30</td>
</tr>
<tr>
<td>R&amp;D personnel (Percentage of population in the labour force - numerator in full-time equivalent (FTE))</td>
<td>1.3046</td>
<td>1.335</td>
<td>1.3956</td>
<td>1.452</td>
<td>1.4945</td>
<td>1.5296</td>
<td>1.5903</td>
</tr>
<tr>
<td>Patent applications (Per million inhabitants)</td>
<td>140.96</td>
<td>139.40</td>
<td>143.31</td>
<td>148.17</td>
<td>148.78</td>
<td>147.37</td>
<td>151.75</td>
</tr>
<tr>
<td>Real GDP per capita (Chain linked volumes (2010), euro per capita)</td>
<td>29,280</td>
<td>29,730</td>
<td>30,440</td>
<td>30,910</td>
<td>31,300</td>
<td>29,340</td>
<td>30,900</td>
</tr>
<tr>
<td>Investment share of GDP by institutional sectors (Percentage)</td>
<td>20.13</td>
<td>20.49</td>
<td>20.81</td>
<td>21.19</td>
<td>22.39</td>
<td>22.21</td>
<td>22.19</td>
</tr>
<tr>
<td>Young people neither in employment nor in education and training (Percentage of total population)</td>
<td>15.3</td>
<td>14.6</td>
<td>14.0</td>
<td>13.3</td>
<td>12.8</td>
<td>14.0</td>
<td>13.0</td>
</tr>
</tbody>
</table>

Source: Eurostat

Table 4. Pearson correlation for all variables

<table>
<thead>
<tr>
<th></th>
<th>R&amp;D_Exp</th>
<th>R&amp;D_Pers</th>
<th>PATENT_App</th>
<th>GDP_Per capita</th>
<th>GDP_Inv</th>
<th>UNEMPLOYED_Young</th>
</tr>
</thead>
<tbody>
<tr>
<td>R&amp;D_Exp</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R&amp;D_Pers</td>
<td>0.9402</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PATENT_App</td>
<td>0.8432</td>
<td>0.9436</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP_Per capita</td>
<td>0.2488</td>
<td>0.5046</td>
<td>0.6604</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>GDP_Inv</td>
<td>0.9293</td>
<td>0.9364</td>
<td>0.8740</td>
<td>0.5038</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>UNEMPLOYED_Young</td>
<td>-0.6521</td>
<td>-0.8205</td>
<td>-0.8795</td>
<td>-0.8883</td>
<td>-0.8245</td>
<td>1</td>
</tr>
</tbody>
</table>

Source: Author

In general terms, correlation coefficients show that the most significant effects of technological progress are in terms of economic growth (GDP_Inv) and the reduction of unemployment (UNEMPLOYED_Young). By contrast, the correlations with wealth per capita (GDP_Per capita) are less strong.

However, while all variables representative of technological progress have positive relationships with social welfare indicators, some connections stand out for their intensity. In particular, concerning the average standard of living of the population (GDP_Per capita) the most significant effect is exerted by patent applications. This result is particularly significant since, compared with the indicators of technological progress indicating the input of the innovation process, i.e. the resources invested in it, the patent application indicator represents the output of the research, that is, the result that has materialized in innovation. This means that innovation improves the standard of living of the population.

For models 1, 2 and 3, since the independent variables are expressed in different units of measurement, the study calculated the standardized regression coefficients to make the data comparable and useful for identifying the most weighted coefficients.
Table 5 presents the standardized dependent and independent variables.

<table>
<thead>
<tr>
<th>Hypothesis</th>
<th>Regression equation</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1</td>
<td>GDP Per capita = 0.0000 - 1.5431 * R&amp;D_Exp + 0.9531 * R&amp;D_Pers + 1.0623 * PATENT_App</td>
</tr>
<tr>
<td>H2</td>
<td>GDP_Inv = -0.0000 + 0.4574 * R&amp;D_Exp + 0.4159 * R&amp;D_Pers + 0.0959 * PATENT_App</td>
</tr>
<tr>
<td>H3</td>
<td>UNEMPLOYED_Young = -0.0000 + 0.7834 * R&amp;D_Exp - 0.9468 * R&amp;D_Pers - 0.6467 * PATENT_App</td>
</tr>
</tbody>
</table>

Source: Author

As regards the H1 hypothesis, while the negative relationship of the average living standard (GDP_Per capita) with R&D expenditure is difficult to interpret, the positive relationship with the share of R&D personnel (R&D_Pers) and with patent applications (PATENT_App) demonstrates the importance of research and innovation in fostering the well-being of the population.

Compared to the H1 hypothesis, the H2 is more consistent and clear as all relationships are positive. In this case, the regression equation shows that economic growth (GDP_Inv) is positively influenced by all independent variables, among which R&D expenditure is the most important.

Finally, with regard to the H3 hypothesis, it is relevant to consider the negative relationship between R&D personnel and the proportion of the population aged 15-29 who are not employed or involved in education or training (UNEMPLOYED_Young). This connection demonstrates the importance of innovation and research for the creation of skilled and equally paid work.

5. CONCLUSION

The analysis of the relationships between technological progress and social sustainability has shown the remarkable complexity of the theme. In fact, alongside virtuous connections, such as those of innovation and research with well-being, economic growth and the employment of young people, there are still other sub-optimal connections. Among these, it seems that the average wealth of the population (GDP_Per capita) is not particularly sensitive to technical progress. From this consideration emerges the need for economic development supported by increasingly advanced technologies to be more inclusive and take place for the benefit of the entire population, in order to achieve effective and equally distributed prosperity.
References


