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# Can Teleworking Lead to Economic Growth during Pandemic Times? Empirical Evidence at the European Union Level

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**Abstract:** Teleworking is known as a way of the future that enhances economic growth as an accumulation of physical as well as human capital. Using digitalization that increase the procedures and services efficiency and reduce the repetitive work of employers by using technology, teleworking improves firm performance by enhancing efficiency, motivation, and knowledge creation. This paper aims to analyze the influence of teleworking, based on its characteristics and determinants under the influence of financial and pandemic crises, on economic growth as measured by GDP growth; this was performed using econometric models from the literature and fuzzy logic. The econometric analysis included a two-step approach regarding the years 2008–2020 (including COVID-19 pandemic period) for the 27 member states of the EU. The research results suggest that access to the Internet, employment ratio, and average wage significantly influenced the teleworking ratio of the employees. Furthermore, the access to the Internet made a significant difference in using teleworking, given the infrastructure that was already created in the first COVID-19 pandemic wave. Employees took advantage of it and continued, at a lower scale, to maintain social distancing, although the measures taken in the second wave were not perceived to be as tough as in the first one.

**Keywords:** telework; COVID-19 pandemic; internet; employment; fuzzy logic



**Citation:** Robu, I.-B.; Dicu, R.-M.; Herghiligiu, I.V.; Sahlian, D.N.; Vuță, M. Can Teleworking Lead to Economic Growth during Pandemic Times? Empirical Evidence at the European Union Level. *Electronics* **2023**, *12*, 154. https://doi.org/10.3390/electronics12010154

Academic Editor: George Angelos Papadopoulos

Received: 13 December 2022
Revised: 22 December 2022
Accepted: 23 December 2022
Published: 29 December 2022



## 1. Introduction

Teleworking is one of the most significant and progressive changes in the work environment, not only in the modern era, but in the history of mankind [1]. One of the first manifestations of teleworking was mentioned in 1957, when the payments of salaries were approved for federal employees for work completed at home. Later, many terms were assigned to this activity, with few to no differences in their content: telecommuting, remote work, distance work, virtual office, or home-based telework [2,3].

When the pandemic was not the main factor that led to teleworking and when it was a choice for the companies, Baruch and Nicholson [4] identified four coordinates of teleworking: occupation, organization, work-family environment, and, last but not least, the individual. On the same note, financial and operational benefits are not enough to justify teleworking, but are also the necessary conditions to operate online, with organizations being stimulated to create individual comfort, [5]. Currently, the four coordinates are still valid when considering the possibility of choosing to telework, but the constraint element is a major factor for assessing them (given the division between essential sectors and other sectors, as can be seen in this paper) [6–8].

Not all occupations allow teleworking, and the year 2020 was self-evident. Retail businesses were majorly affected by the COVID-19 pandemic, as they were not considered

as essential for the population [9,10]. A European Union study on the implications of the COVID-19 pandemic on the labor market and, implicitly, on teleworking identified five categories in which economic sectors can be classified according to the impact of COVID-19 [11]. These are: essential and fully active sectors (food production, utilities, health, and all other sectors identified as essential); active sectors using telework (education, most of public administration, finance, insurance, and telecommunications); partly essential and partly active sectors, in which the activity cannot be carried out by teleworking (retail trade and the manufacture of chemicals and paper); mostly non-essential and partially active sectors, in which the activity cannot be carried out by teleworking (production not mentioned above, construction, as well as the repair of machines and computers); and closed sectors (hotels, restaurants and accommodation, real estate and travel agencies, and leisure and recreation services).

As the pandemic has continued, some retail businesses have moved into the online sphere, which has led to major corporate restructuring. Other businesses have been improved, even they were functional before the pandemic period and operated in fixed-store locations. Likewise, the individual problem is the most complex and the most discussed, given the fact that in many situations, there is the issue of individual comfort [12,13], privacy [14,15], personal life [8,16], and the influence that the Internet can have [17,18]. At the individual level but also at the company level, the problem of Internet access is one of major importance, given the fact that, in absence of this facilitation, the concept of telework could not even be taken into consideration.

However, Internet access comes with the issue of data and personal protection as a threat due to poor security. From an individual point of view, the issue of online surveillance is a necessary component of this working approach, and it comes as a necessity for the user [19].

The concept of Big Brother, introduced by George Orwell in "Nineteen Eighty-Four", has been since used to refer to the increasingly innovative methods of controlling the authorities that lead to the violation of the right to privacy. This is what led to General Data Protection Regulation (GDPR) at the EU level in 14 April 2016, with its implementation date being 25 May 2018. This regulation has been important, due to either a lack of sufficient knowledge of protection mechanisms or insufficiently developed infrastructure, especially in the case of events such as the 2020 pandemic, when companies were in many cases taken by surprise and found themselves unprepared to cope with the transition to an online environment. The Cambridge Analytica scandal of 2018 has further raised the level of concern about privacy in the online environment, with the context that more and more people are becoming connected in the largest network in the world. The costs of successfully implementing a platform designed to facilitate teleworking can be daunting for a company whose asset-related revenue may become sub-unitary.

The purpose of this paper is to study how companies' wages, the Internet infrastructure, and the employment rate affect the intensity of teleworking; in the second part of this research, we investigate how different intensities of teleworking affect the whole economy using fuzzy logic, reflected in the GDP growth from 2008 to 2020.

Thus, the concepts regarding teleworking can be viewed from the perspective of the company and/or of the employee. This research analysis focuses on the data related to employment rate, average wage, and Internet access and their influence on teleworking, considering employees by sex (male and female). Firstly, the relationship is assessed for the period of 2008–2019; the pandemic is then added as an extraordinary circumstance that has changed the perception of teleworking and telecommuting. Europe was the second region in the world (after Asia) that was hit hard by the coronavirus (COVID-19) pandemic of early 2020. As the number of cases spread throughout Europe, which threatened to collapse many health care systems, most European countries implemented unprecedented measures to restrict personal freedoms and economic activity in order to reduce contact between people and thus stop the spread of the virus [20–22]. These measures were broadly similar in all countries of the European Union, but they also differed in some important issues,

such as the harshness of the confinement or the sectors that were considered essential and thus spared from the lockdown.

The research's results will show that, before 2020, all considered factors significantly influenced the choice for teleworking. In the first wave of lockdown in 2020, the employment rate and Internet access were variables of interest, wage not being a factor in choosing to telework, for both males and females. The second wave only brought into attention Internet access, where telework began to be a choice in many sectors. As a contribution, the obtained results allow for the prediction of a future situation of economic growth under teleworking and its determinants. In a situation of uncertainty for European labor markets and changing work conditions and environments, an estimation of the employment implications on these confinement measures can be very useful. Furthermore, such an estimation can also provide some hints about the labor market prospects for the future after the COVID crisis. The last part of the analysis assesses the influence of teleworking on the economic growth at the European level.

For this purpose, the paper is structured into three parts so that it can cover the concept of teleworking from a theoretical perspective to empirical results at the European Union level. The first part includes relevant papers related to the topic referring to the topic's characteristics over time, the situation during the COVID-19 pandemic, but also the benefits and risks of this type of employment. This part ends with the proposed hypotheses, which are to be tested using data and models for analysis, presented in the second part of the paper. The third part includes the results and discussions.

## 2. Literature Review and Hypothesis Development

In 1973, Jack Nilles, a physicist from National Science Foundation, proposed the terms teleworking and telecommuting. Their purpose was to help reduce employee turnover rate for an insurance company by allowing the work from another place than the office [23].

Known as a term which describes a wide range of ways that allow employees to work outside the employers' headquarters [24], telework has become a benchmark for COVID-19 companies, with very few exceptions (essential sectors) [25–27]. In actuality, most companies have searched for ways in which to facilitate telework, with more than 3.4 billion people in 84 countries having been confined to their homes, as was estimated in late March 2020 [28].

Having been brought to companies' attention for almost five decades, discussions took place and papers were written in order to explain this concept [29–31], its influence factors [18,32–35], and the forms that it took in order to explain the choices of both companies and employees in choosing how to perform their duties, presented and assumed, in the job description. For instance, Bailey and Kurland [36] described four types of telework: home-based telecommuting, satellite centers, neighborhood work centers, and mobile working (in airports, in the car, or in clients' offices), all of them approved by the employer. Additionally, Qvortrup [37] identified two major types of employees that perform their duties using telework: nomadic teleworkers and home-based workers. In the pandemic context, the first category is not so common, and the second one was majorly used in order to ensure social distancing.

The effects of telework can be analyzed from a double perspective. On the one hand, there are positive effects: low pressure from the employer and high autonomy of the employee, which allows them to dedicate themselves to their families [38]. The negative effects translate into ambiguity of job size and limited support and feedback [39]. Firsov et al. [40] raises the question of the future of telework in the post-pandemic period and focuses on the transition from the question "Do we have the right technology to cope with telework?" to "Do we have proper personnel policies and training conditions?".

Despite numerous advantages of teleworking, the high risks associated with it can be complex and can be viewed from many perspectives. A first perspective is provided by the data and how the virtual environment can affect both the company and the individual. In the current pandemic context, the Ponemon Institute [41] created an index called the

Cyber Risk Index (CRI), which included five risk categories: data risk, cyber risk, risk of lack or precariousness of infrastructure, human capital risk, and operational risk. Basically, these risks cover a wide range and are not identified for the first time. They are present in the literature and in practice in previous years, but are now more obvious in the current context where telework has turned from an option into an obligation. Among these risks, the following risks could be mentioned: the inability of companies to prevent/combat cyber-attacks [42–46]; insufficient allocation of financial resources needed to develop work infrastructure, including security protocols [47,48]; low level of qualification and/or negligence of employees forced to adapt to telework [49]; and loss of information related to intellectual property and patents, destruction of equipment, and loss of customers. Basically, the risk areas that are of particular importance are that of budget, time, quality, people, and equipment [47,50,51].

The risks can also be analyzed at the individual, organizational, and national level. In the twentieth century, Baruch and Nicholson [4] identified a series of risks structured according to the mentioned categories, which can be easily extrapolated to the society of the years 2020–2021. The individual has less social interaction and cannot impose his point of view, which is transmitted at the company level, who in turn becomes unable to control and motivate employees and no longer benefits from the advantages of teamwork. Overall, society loses its ability to communicate and act in solidarity, and thus individuals are atomized and isolated from social institutions [52,53]. The way in which people were able to manage adversity and respond to the solutions for containing the pandemic reflected their resilience, where age was a major factor for adaptability [2,54].

From what could be observed, the risks are current, but also inevitable. When being a part of the economic life of any entity, some risks are necessary; some are tolerable for considering them in decision-making process and other are intolerable, with a negative impact on company's performance. The current context, which affects the planet, imposes inevitable, large-scale risks; however, the decision-making process of each company must find solutions within the limits of its human and financial capital [55,56].

Teleworking was already seen as a future demand almost thirty years ago, identifying some key features of this form of work [57]: openness to a broad market when it comes to employment; increased productivity; the possibility of part-time employment for the efficiency of cyclical activities; and encouraging females to build a career as well as males, when it comes to integrating various professions, thus leading to a synergy of activities that would not have been possible in the traditional system.

To analyze how the scientific community has looked at teleworking over time, the query of the Web of Science database for the range of 2008–2020, after using the keywords teleworking and telecommuting, resulted in 756 scientific papers. The choice for the two words is justified by the differences between them, despite the fact that many authors interchangeably use them as representatives for work using telecommunications and computer-based technology [36,58,59]. Authors who consider them different assert that teleworking is not only referring to working from home, but to working from any place of convenience that is not the office (libraries, Internet cafes, hotel rooms, client offices, and even on trains and in automobiles), whereas telecommuting only refers to working at home to the benefit of the work–family relationship [60–62].

Using graph theory, the frequency of occurrence of the words examined in these papers was calculated, as shown in Figure 1.

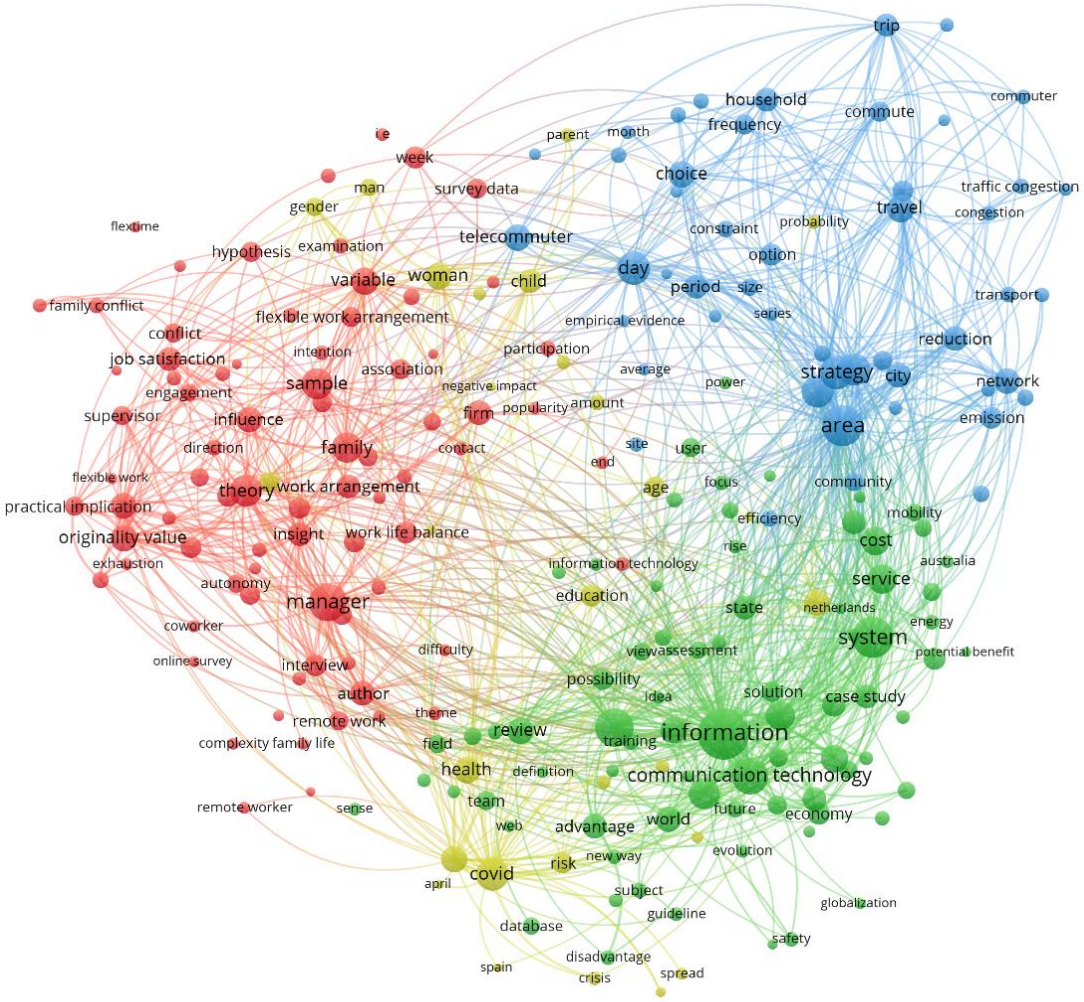



**Figure 1.** Map association of terms and concepts related to teleworking or telecommuting.

The concepts, as seen in Figure 1, mark clusters of concepts, which are represented in different colors and describe the phenomenon of telework as a whole. Within the clusters, different sizes of spheres can be noticed, which account for the frequency and density of using the concept and/or term in scientific papers. Moreover, interconnections between terms and concepts are normal and are expected to occur in scientific papers. Thus, the distance between spheres shows the relatedness of concepts/terms. The clusters, as presented in the Figure 1, account for the four dimensions of teleworking, by combining work with family, using IT&C.

The clusters that were identified are the following:

- Red—establishing the theoretical framework (the planning);
- Blue—commuting as a consequence of teleworking and telecommuting (the action);
- Green—technology as an essential role in telework (the infrastructure);
- Yellow—the pandemic crisis initiated by COVID-19 (the agent factor).

In this context, the association of the terms are analyzed, keeping in mind the frameworks and theoretical aspects, the planification of a company, and/or the employee when having the opportunity to work from home (the red associations).

Analyzing the blue associations, a more pragmatical approach was identified, which focuses on the commuting concept, and it could be seen as a consequence of telework (as a means that it can offer); the green cluster shows a more technical vision and focuses on technology, information, service, and ways of training. The yellow cluster marks a more recent concern regarding the worldwide pandemic, which started a crisis in more than just

the health department. COVID-19 changed humanity in its way of thinking and forced companies to adjust their infrastructure in order to resist and maintain activity.

The same study analyzes the situation of the five categories of sectors at the end of the closure period. The results show that Malta registered 15.68% of the economy as closed, ranking first place, followed by Spain (14.19%) and Cyprus (14.16%). Lithuania (with 7.61%), Poland (with 6.63%), and Romania (with 4.71%) occupy the last rankings. Although most sectors resumed their activity in the second half of 2020 and kept the regulatory distance to prevent infection with the Coronavirus, on 31 December 2020, the situation of the stringency index in the European Union is presented in Figure 2.

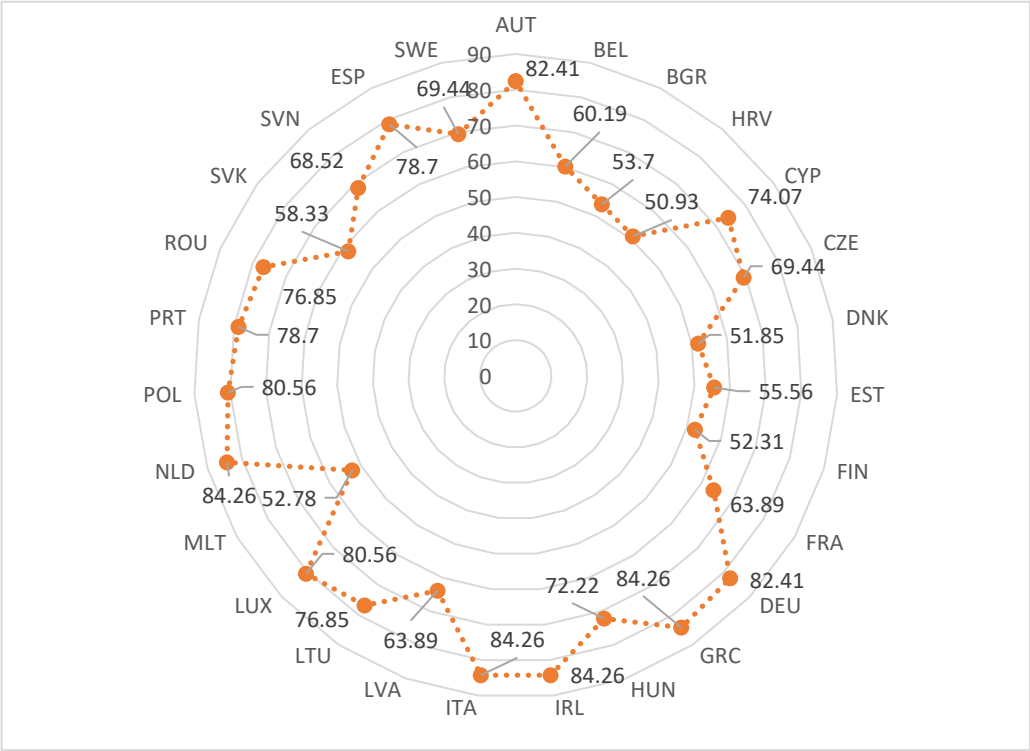



**Figure 2.** Stringency index on 31 December 2020 at the EU level [63].

It could be noted that the measures majorly relaxed in Croatia (50.93 points), Denmark (51.85 points), Finland (52.31 points), and Malta (52.78 points). The top countries with the most restrictive conditions at the end of 2020 included the Netherlands, Italy, and Greece, with a number of 84.26 points, followed by Germany and Austria with 82.41 points and Luxembourg and Poland, each with 80.56 points.

There are three important changes that resulted from the pandemic, and the switch to teleworking is one of them (93% of companies have resorted to this work model), along with changing customer needs and expectations (63%) and the movement of customers' major purchases to the online environment (62%). Companies adapted 40 times faster than expected to the new work conditions, although respondents acknowledged that the necessary changes were too much of a shock to the established ways of working, as the IT infrastructure proved itself insufficient or organizational conditions prevented employers from hiring and executing the necessary changes. Regarding the future, 54% of respondents believe that teleworking in organizations will continue after the end of the pandemic as opposed to 23% of respondents, who considered that the change will not be permanent [64].

The main drivers of economic growth are represented by the accumulation of physical as well as human capital. GDP per capita is a well-known proxy for measuring economic growth under the influence of policy and institutions in growth and investment equations [65].

Economic growth and business continuity are significantly affected by digitalization processes that add value to businesses and the economy [66–68]. Digitization has led to the emergence of new jobs and the relocation of existing jobs, with a strong impact on the employment ratio [69,70]; furthermore, a greater integration of digitalization in a company's activities determine lower manufacturing costs [70].

Taking into consideration the changes that resulted from the pandemic period that had a significant impact on economic growth, it is necessary to use artificial intelligence and IT infrastructure to increase the procedures and services efficiency and reduce the repetitive work of employers by using technology that has a strong impact on productivity [70,71]. Teleworking improves firm performance, firstly by enhancing the efficiency, motivation, and knowledge creation and secondly by the reductions that free up resources for productivity using digital infrastructure [72].

Based on the presented literature framework in this study, the following two research hypotheses are proposed:

**$H_1$:** *IT infrastructure (measured by Internet access), where average wage and employment ratio have a significant influence on the teleworking integration.*

**$H_2$:** *In the pandemic context, teleworking has a positive influence on economic growth comparative to the pre-pandemic period.*

## 3. Research Methodology and Design

In order to assess the influence of telework on GDP growth for the period of 2008–2020, a statistical approach is proposed to validate the research hypotheses [73]; hence, the following research objectives are developed:

**$O_1$:** *Estimation and testing of the influence of Internet access, average wage, and employment ratio on the teleworking ratio, considering the total population, but also the division by sex;*

**$O_2$:** *Estimation and testing of the influence of telework on the GDP growth, considering the total population, but also the division by sex;*

**$O_3$:** *Estimation of the GDP growth probability distribution under the influence of teleworking based on fuzzy logic.*

Considering the period of 2008–2019, we determined the estimation parameters for the telework ratio as the dependent variable, considering the influence of Internet access, average wage, and employment rate, for the 27 EU current member states. Based on these parameters, the value of telework for 2020 was estimated in the absence of the COVID-19 pandemic's influence.

In the next step of our study, the estimation parameters for the influence of telework on the GDP growth are considered for the period of 2008–2019 and for 2020 as estimates, as well as for 2020, considering the telework for two different waves (January–May and June–July). Furthermore, the study analyzes the influences considering the sex of the teleworkers (male and female).

### *3.1. Sample and Data Source*

The data used in the empirical analysis, specifically those for measuring economic prosperity and the sustainable and financial inputs at the macroeconomic level, are presented in Table 1.

**Table 1.** Summary description of variable used.

| | Variables | Type | Description | Source |
|---|---|---|---|---|
| Dependent variable | GDP growth (GDP) | Numeric variable | The value of the Gross Domestic Product per capita for the EU27 | World Bank for the period of 2008–2020 |
| Telework | Telework (Tw, TwM, and TwF) | Numeric variable | The percentage of the employed population who used telework.<br>1. Total<br>2. Male<br>3. Female | World Bank for the period of 2008–2019<br>European Commission for the period of 2020 |
| Independent variables | Internet access (Int) | Numeric variable | Individuals using the Internet (% of population). | World Bank, for the period of 2008–2019 |
| | Average wage (Aw) | Numeric variable | Average wages are obtained by dividing the national accounts-based total wage bill by the average number of employees in the total economy. | OECD database for the period of 2008–2019 |
| | Employment rate (Emp) | Numeric variable | The extent to which available labor resources (people available to work) are being used. | OECD database for the period of 2008–2019 |
| Period | 2008–2019<br>2020_est<br>2020_1w<br>2020_2w | Ordinal variable | The years until the pandemic.<br>The year for which the estimated values for telework were calculated, considering the proposed model.<br>The first pandemic wave (January–May).<br>The second pandemic wave (June–July). | |

Because the data for Bulgaria, Croatia, Cyprus, Malta, and Romania were not available on the OECD database, it was separately collected from each country's statistics, keeping the rationale behind the calculation of the variable. The analysis was carried out in two stages:

- The interval of 2008–2019, which determined the estimated values for the telework predictor for 2020;
- The first (1w) and second wave (2w) of 2020. According to the EU, the ratio of teleworkers in the total employed population was considered for the periods January–May (1st wave of the pandemic) and June–July (2nd wave of the pandemic).

Thus, the year 2020 will be analyzed from three angles (the estimates and two separate waves).

### *3.2. Models for Data Analysis*

To analyze the influence of the dependent variables on teleworking, the study proposes the following econometric model (objective $O_1$):

$$Tw_{it} = \beta_0 + \beta_1 \cdot Int_{it} + \beta_2 \cdot Aw_{it} + \beta_3 \cdot Emp_{it} + Year\ fixed\ effects + \varepsilon_{it} \quad (1)$$

where:

$i$—values from 1–27, corresponding to the EU member states;

$t$—years between 2008–2019;

$\beta_{i=1,\ldots,3}$—the model parameters;

$\varepsilon_{it}$ —the error component, a random variable: $\varepsilon_{it} \sim N(0,1)$.

In the next phase of this research, the influence of the estimated value of telework on the economic growth was tested for the period of 2008–2019, starting with the Bangemann Report [74] and considering work as recent as Mello's [61] research. Given the exceptional circumstances of 2020, the influence of telework on GDP growth for the pandemic year was added to the analysis, considering the estimated value for telework but also the values for the two waves:

$$GDP_{ik} = \gamma_0 + \gamma_1 \cdot Tw_{ik} + Year\ fixed\ effects + Country\ fixed\ effects + \varepsilon_{ik} \quad (2)$$

where:

$i$—values from 1–27, corresponding to the EU member states;

$k$—years between 2008 and 2020.

For analyzing the influence of a variable for a specific period, considering a reference period, the following related models were considered:

- Comparing the influence of the estimated values of telework for 2020 on the economic growth, with the values corresponding to the first wave of the pandemic (model 1—Equation (3)):

$$GDP_{i2020} = \delta_0 + \delta_1 \cdot Tw_i + \delta_2 \cdot Year_{2020\_est} + \delta_3 \cdot Year_{2020\_1w} + \delta_4 \cdot Tw_i \cdot Year_{2020\_est} + \delta_5 \cdot Tw_i \cdot Year_{2020\_1w} + \varepsilon_i \quad (3)$$

- Comparing the influence of the estimated values of telework for 2020 on the economic growth, with the values corresponding to the second wave of the pandemic (model 2—Equation (4)):

$$GDP_{i2020} = \zeta_0 + \zeta_1 \cdot Tw_i + \zeta_2 \cdot Year_{2020_{est}} + \zeta_3 \cdot Year_{2020_{2w}} + \zeta_4 \cdot Tw_i \cdot Year_{2020\_est} + \zeta_5 \cdot Tw_i \cdot Year_{2020\_2w} + \varepsilon_i \quad (4)$$

- Comparing the influence of the estimated values of telework for 2020 on the economic growth, with the values corresponding to both waves of the pandemic (model 3—Equation (5)):

$$GDP_{i2020} = \lambda_0 + \lambda_1 \cdot Tw_i + \lambda_2 \cdot Year_{2020\_est} + \lambda_3 \cdot Year_{2020\_1w} + \lambda_4 Year_{2020\_2w} + \lambda_5 \cdot Tw_i \cdot Year_{2020\_est} + \lambda_6 \cdot Tw_i \cdot Year_{2020\_1w} + \lambda_7 \cdot Tw_i \cdot Year_{2020\_2w} + \varepsilon_i \quad (5)$$

- Comparing the influence of the values of telework for both waves in consideration of 2020 on the economic growth (model 4—Equation (6)):

$$GDP_{i2020} = \theta_0 + \theta_1 \cdot Tw_i + \theta_2 \cdot Year_{2020\_1w} + \theta_3 \cdot Year_{2020\_2w} + \theta_4 \cdot Tw_i \cdot Year_{2020\_1w} + \theta_5 \cdot Tw_i \cdot Year_{2020\_2w} + \varepsilon_i \quad (6)$$

where:
*GDP*—dependent variable, representing the economic growth;
$\delta,\ \zeta, \theta, \lambda_{i=1,\ldots,7}$ —the models' parameters;
$\varepsilon_i$—the error component, a random variable: $\varepsilon_i \ \sim \ N(0,1)$.
The presented models are considered for the entire population, but also by sex (males and females).

### *3.3. Using Fuzzy Logic to Assess GDP Growth Probability Distribution under the Influence of Teleworking*

The fuzzy approach has the capacity to simulate human reasoning and to predict various outcomes [75–77]. Fuzzy algorithms could be characterized as a type of calculation approach that is robust and implies transfer functions [78], i.e., "knowledge is encoded in antecedent-consequent structure form" [79,80], which computes linguistic variables that involve understanding associated with the (i) variables' names, (ii) variables' term-sets, (iii) discourse universe, (iv) syntactic rules, and (v) semantic rules [81–84].

Fuzzy models have the ability to include various types of data, probabilistic logic, and uncertainty [83]. Hence, the fuzzy approach through a computing framework (fuzzy inference system (FIS) [83]), is based on fuzzy sets, if-then rules, and associated reasoning [80,81,84].

The FIS fundamentally includes four main modules: the fuzzifier, inference engine, defuzzifier, and fuzzy system definition [83]—Figure 3 [80].

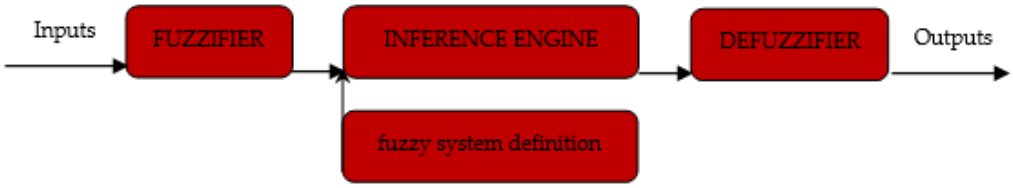
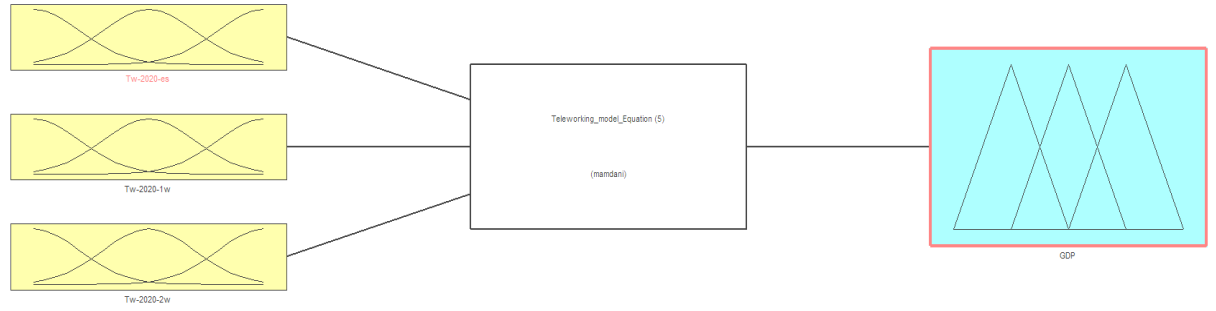



**Figure 3.** FIS block diagram [80].

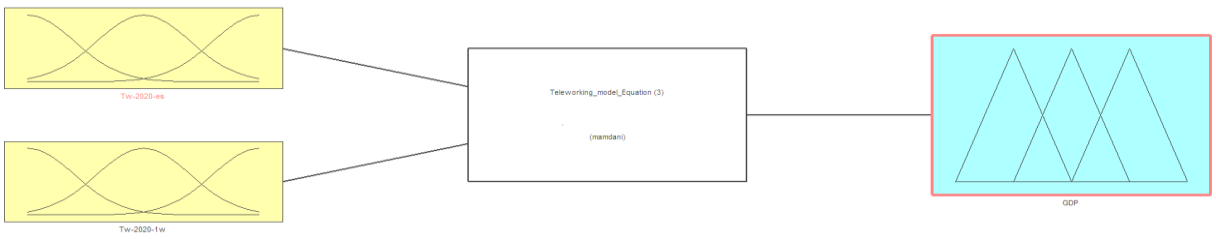
Hence, the fuzzy modeling algorithm assumes: *fuzzification*—a process that converts normalized inputs into linguistic variables using membership functions; *inference*—a process that links fuzzy inputs and outputs based on a series of rules where: *IF x is A AND y* is *B*, *THEN z* is *C*, where *A*, *B*, and *C* are linguistic values defined by the fuzzy set associated with the *X*, *Y*, and *Z* analysis universe; *defuzzification*—a process that transforms all individual fuzzy rules outputs into one single crisp output value based on different defuzzification techniques; in this study, the centroid method is used [80,82,85–88].

The Mamdani and Sugeno methods are considered to be the most used fuzzy inference techniques because these have the capacity to integrate expert knowledge in fuzzy rules. The Sugeno method is usually used in control problems, being more feasible for dynamic nonlinear systems. The Mamdani fuzzy system could be characterized as more human-input compatible, more intuitive, and more interpretable [80,81,83,84]. Hence, in this study, Mamdani fuzzy-based models were developed in order to estimate the GDP growth probability distribution under the influence of teleworking.

In this study, starting from Equations (3)–(5) and based on a fuzzy inference system, the following fuzzy models were considered (see Figure 4).




(**a**)




(**b**)

**Figure 4.** *Cont.*


(**c**)

**Figure 4.** Fuzzy inference systems diagrams (**a**–**c**) for GDP growth probability distribution under the influence of teleworking assessment models. (**a**) FIS Model 1 based on Equation (5); (**b**) FIS Model 2 based on Equation (3); (**c**) FIS Model 3 based on Equation (4).

Considering variables statistical distributions, the GDP growth (*GDP*) and teleworking (*Tw*) for the estimated (*es*), first wave (*1w*), and second wave (*2w*) in the fuzzy models were considered. For these variables, the following fuzzy set rules was proposed, based on their statistical association:

- Rules for FIS model 1 based on Equation (5):

**Rule 1:** If (Tw-2020-es is Low) and (Tw-2020-1w is High) and (Tw-2020-2w is High), then (GDP is Low)
**Rule 2:** If (Tw-2020-es is Medium) and (Tw-2020-1w is Medium) and (Tw-2020-2w is Medium), then (GDP is Medium)
**Rule 3:** If (Tw-2020-es is High) and (Tw-2020-1w is Low) and (Tw-2020-2w is Low), then (GDP is High)

- Rules for FIS model 1 based on Equation (3):

**Rule 1:** If (Tw-2020-es is Low) and (Tw-2020-1w is High), then (GDP is Low)
**Rule 2:** If (Tw-2020-es is Medium) and (Tw-2020-1w is Medium), then (GDP is Medium)
**Rule 3:** If (Tw-2020-es is High) and (Tw-2020-1w is Low), then (GDP is High)

- Rules for FIS model 1 based on Equation (4):

**Rule 1:** If (Tw-2020-es is Low) and (Tw-2020-2w is High), then (GDP is Low)
**Rule 2:** If (Tw-2020-es is Medium) and (Tw-2020-2w is Medium), then (GDP is Medium)
**Rule 3:** If (Tw-2020-es is High) and (Tw-2020-2w is Medium), then (GDP is High)
**Rule 4:** If (Tw-2020-es is High) and (Tw-2020-2w is Low), then (GDP is High)

The modeling was performed in the MATLAB tool.

## 4. Results and Discussions

The study presents a series of descriptive statistics for the analyzed variables, the values of the Pearson correlation coefficients, and the estimations of the parameters associated with the proposed regression models. The descriptive statistics for the interest variables are presented in Table 2.

**Table 2.** Summary statistics for the interest variables.

| Variables | Tw | TwM | TwF | GDP (%) | Int | Aw | Emp |
|---|---|---|---|---|---|---|---|
| Minimum | 0.3 | −0.11 | 0.4 | −14.8 | 32.42 | 231.61 | 41.93 |
| Maximum | 53.3 | 54.4 | 51.6 | 25.4 | 98.14 | 5796.36 | 78.15 |
| Mean | 14.4251 | 14.687 | 14.1294 | −0.1077 | 75.7537 | 2763.497 | 63.8056 |
| Std. Deviation | 10.51151 | 11.0558 | 10.10459 | 4.71163 | 13.38284 | 1345.411 | 8.47952 |
| Skewness | 0.819 | 0.809 | 0.852 | −0.337 | −0.636 | 0.162 | −0.485 |
| Kurtosis | 0.13 | −0.046 | 0.311 | 1.906 | 0.051 | −0.932 | −0.653 |

The ANOVA analysis results for the economic growth recorded by the EU member states is presented in Table 3.

**Table 3.** ANOVA analysis results for the economic growth.

| Factors | Deal Values | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|
| GDP growth | Between Groups | 26 | 31.126 | 1.442 | 0.077 |
| | Within Groups | 378 | 21.585 | | |
| | Total | 404 | | | |

The ANOVA results presented in Table 3 show a significant difference at the 10% level between the means of the GDP growth when considering the 27 EU member states. The significance is underlined by the F-test (F (26,378) = 1.442). Performing the LSD post hoc test, if the example of Romania is considered, its economic growth is significantly different from the one recorded by Croatia (sig. = 0.089), Greece (sig. = 0.004), Italy (sig. = 0.027), Portugal (sig. = 0.073), and Spain (0.043). Furthermore, the differences between the mean economic growth compared with the aforementioned countries show that, for the considered period, the GDP growth of Romania is superior. Thus, Romania is comparable with other developed economies from the EU in terms of economic growth. Among all 27 countries, the one that stands out is Ireland, with its GDP growth being significantly different from and superior to most of the other 26 countries.

In Table 4 that fallows, it could be observed the parameter estimates for teleworking.

**Table 4.** Parameter estimates for teleworking (Tw-es).

| Parameter | All | Male | Female |
|---|---|---|---|
| Intercept | −7.671 *** | −8.639 *** | −6.199 *** |
| Int | 5.098 *** | 5.693 *** | 4.236 *** |
| Aw | 9.279 *** | 9.645 *** | 8.495 *** |
| Emp | 3.194 *** | 3.229 *** | 2.958 *** |
| Year | Yes | Yes | Yes |
| R2 | 0.677 | 0.700 | 0.629 |
| Adj. R2 | 0.663 | 0.686 | 0.612 |
| N | | 324 | |

*** represent level of significance of 1%.

As expected for the period of 2008–2019, the Internet access, average wage, and employment rate have positive influences on telework. The positive influence of Internet access was also part of the results of Bălăcescu et al. [89], and Pabilonia and Vernon [90] argued that teleworkers earn premium wages, thus preferring this type of work. According to Vilhelmson and Thulin [91], the gainfully employed people, with access to telecommunication technologies, are teleworkers for over 20%, which is consistent with research findings. In the same regard, it could be noted that the chosen influence factors affect males more than females, with previous research also showing that teleworkers with high occupational status and high income are usually male [92,93]. This is to be expected due to the fact that females often prefer to telework when they want to combine housework with career, as stated by Pordelan et al. [94] and Gonzáles Ramos and García-de-Diego [95]. At the same time, males prefer to telework when they want to expand their portfolio of their professional skills, which allows them to increase their income. This is also presented in Figure 5.

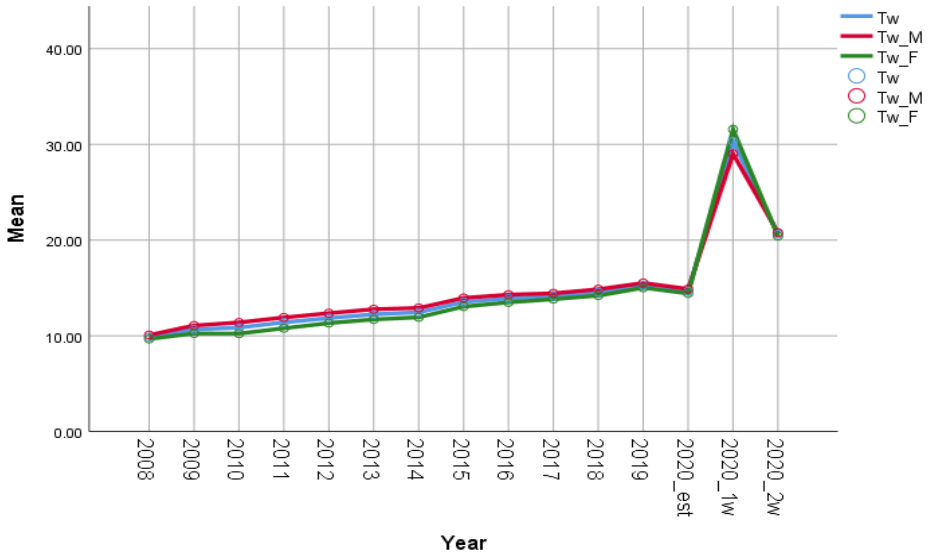



**Figure 5.** The percentage of teleworkers for 2008–2020.

The data presented in Figure 5 (processing conducted using Eviews 10 software) show us that male employees preferred the option to telework during 2008–2019, but in the pandemic crisis, a switch was noticed that put female employees in front. To explain this, it must be understanded that males prefer to telework in order to provide more for their family, while females, if they choose to telework, is because they do not want to neglect the professional career while taking care of their children. In the COVID-19 scenario, when the schools were closed due to the precautions taken by the authorities, more females chose to telework as a compromise solution to combine work and family; for males, if they had the opportunity to go out to perform office tasks, they chose this option. This result is consistent with the research of Belzunegui-Eraso and Erro-Garcés [96], who asserted that a teleworker's profile during the pandemic was identified as usually female workers who had been provided a computer workplace in their home by their employer [95].

According to data in Table 5, the telework negatively influenced the economic growth of the EU member states.

**Table 5.** Parameter estimates for GDP growth (%).

| Parameter | Tw | TwM | TwF |
|---|---|---|---|
| Intercept | −4.588 *** | −4.536 *** | −4.768 *** |
| Tw | −2.363 ** | −2.514 ** | −2.112 ** |
| Year | Yes | Yes | Yes |
| Country | Yes | Yes | Yes |
| R2 | 0.766 | 0.767 | 0.765 |
| Adj. R2 | 0.74 | 0.74 | 0.739 |
| N | | 405 | |

** and *** represent levels of significance of 5% and respectively 1%.

The economic growth and percentage of employees who use telework is graphically represented in Figure 6.

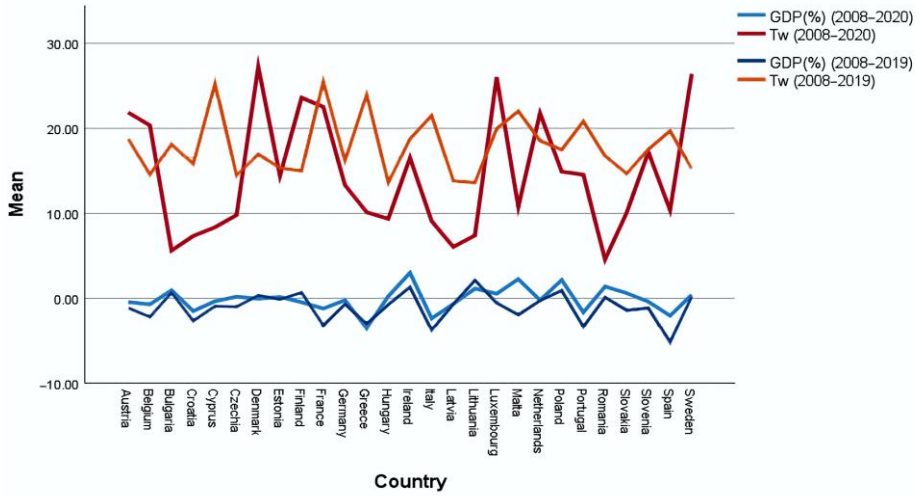



**Figure 6.** The mean values of economic growth and the teleworking ratio for the period 2008–2020.

As represented in Figure 6, for Ireland, the choice to telework led to economic growth, in contrast to Romania or Bulgaria, where employees that used telework did not have a positive impact on the GDP growth. For developed economies such as Denmark, Finland, or Luxembourg, the choice to telework was not the best choice for economic growth, given the fact that the increase in the percentage of employees who worked outside the office did not lead to a positive influence on GDP.

The parameter estimates for the models that compare different periods from 2020 with a reference period are presented in Table 6.

Based on Table 6, GDP growth (*GDP*) was significantly and negatively influenced by the teleworking values, but the period for which it was computed shows mixed results. Thus, the estimated values for teleworking for 2020 significantly influence the economic growth, and the results show that teleworking would have not been effective in this regard.

The transition to teleworking was difficult, and the shock of declining activity due to low consumption and production is reflected in the negative influence of teleworking on GDP growth, a result which is consistent with the ones attained by Slabe-Erker and Primc [97] and of Christidis et al. [98]. Teleworking was a solution that a lot of businesses used to continue as a going concern, but not at the pre-pandemic level; thus, teleworking's negative influence on the GDP is shown. As indicated by the results obtained, teleworking is not a factor of positive influence if the economic growth is intended. This study contradicts the results of Bran et al. [99], who compared the influence of teleworking and traditional work on economic growth and found that the first incurs a greater impact.

There is a caution about the generalizability of these findings, given the fact that there have been changes in the countries' approaches as the pandemic has progressed and as the medical findings led to opening the borders [100]. On the positive side, organizations may continue to promote telework as an option that may attract talent among younger employees while establishing positive relations with external stakeholders if the companies consider the wellbeing of the employees and the impact on the environment. Environmental responsibility is a bonus for firms that adopt telework, allowing employees to work from alternate locations, even if going to the office is no longer dangerous or impossible.

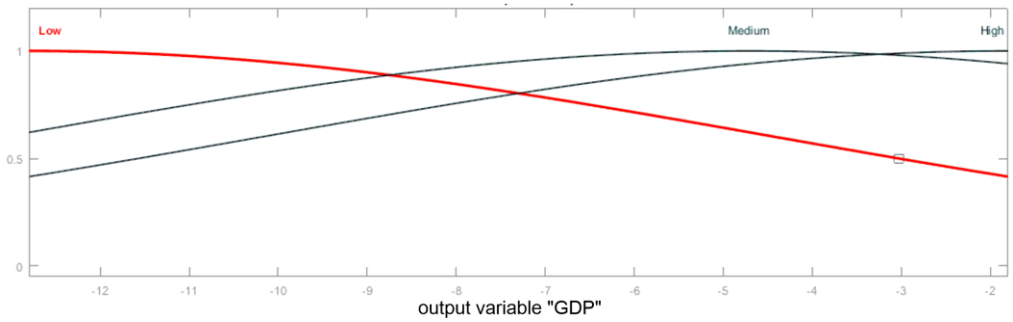
For the fuzzy logic analysis, the membership functions included in the FIS models (1–3) are presented as follows:

In Figure 7, the membership functions are presented for *Tw–es*, *Tw–1w*, and *Tw–2w* as the input variables and for GDP growth (*GDP*) as the output variable. In this study, Gaussian membership functions are proposed, making it easier to simulate human reasoning, which is adequate for this research approach.

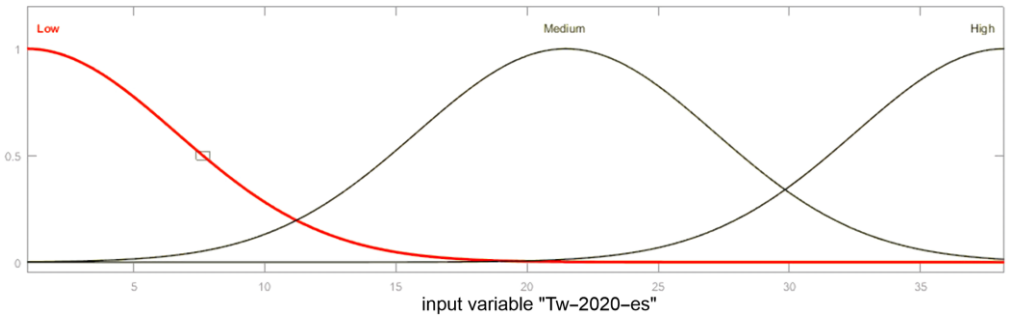
**Table 6.** Parameter estimates associated with GDP for 2020.

| | All | Male | Female |
|---|---|---|---|
| **Model 1 (Equation (3))** | | | |
| Intercept | −2.152 ** | −2.959 *** | −1.663 |
| Tw | −2.614 ** | −2.644 ** | −2.397 ** |
| [Year = 2020_es] * Tw | 2.452 ** | 2.454 ** | 2.282 ** |
| [Year = 2020_1w] * Tw | 0.0 | 0.0 | 0.0 |
| [Year = 2020_es] | −2.494 ** | −2.447 ** | −2.345 ** |
| [Year = 2020_1w] | 0.0 | 0.0 | 0.0 |
| **R2** | **0.132** | **0.135** | **0.113** |
| **Adj. R2** | **0.080** | **0.084** | **0.060** |
| **Model 2 (Equation (4))** | | | |
| Intercept | −3.339 * | −3.486 *** | −3.611 *** |
| Tw | −2.328 ** | −2.520 ** | −1.941 * |
| [Year = 2020_es] * Tw | 2.327 ** | 2.502 ** | 1.967 * |
| [Year = 2020_2w] * Tw | 0.0 | 0.0 | 0.0 |
| [Year = 2020_es] | −2.158 ** | −2.298 ** | −1.828 * |
| [Year = 2020_2w] | 0.0 | 0.0 | 0.0 |
| **R2** | **0.110** | **0.126** | **0.081** |
| **Adj. R2** | **0.056** | **0.073** | **0.025** |
| **Model 3 (Equation (5))** | | | |
| Intercept | −3.422 *** | −3.566 *** | −3.695 *** |
| Tw | −2.386 ** | −2.577 ** | −1.986 * |
| [Year = 2020_es] * Tw | 2.385 ** | 2.560 ** | 2.013 ** |
| [Year = 2020_1w] * Tw | 0.125 | 0.374 | −0.197 |
| [Year = 2020_2w] * Tw | 0.0 | 0.0 | 0.0 |
| [Year = 2020_es] | −2.212** | −2.351** | −1.870 * |
| [Year = 2020_1w] | 0.517 | 0.222 | 0.806 |
| [Year = 2020_2w] | 0.0 | 0.0 | 0.0 |
| **R2** | **0.152** | **0.164** | **0.122** |
| **Adj. R2** | **0.096** | **0.109** | **0.063** |
| **Model 4 (Equation (6))** | | | |
| Intercept | −3.557 *** | −3.720 *** | −3.804 *** |
| Tw | −2.480 ** | −2.688 ** | −2.044 ** |
| [Year = 2020_1w] * Tw | 0.130 | 0.390 | −0.203 |
| [Year = 2020_2w] * Tw | 0.0 | 0.0 | 0.0 |
| [Year = 2020_1w] | 0.537 | 0.232 | 0.830 |
| [Year = 2020_2w] | 0.0 | 0.0 | 0.0 |
| **R2** | **0.215** | **0.232** | **0.171** |
| **Adj. R2** | **0.168** | **0.186** | **0.121** |

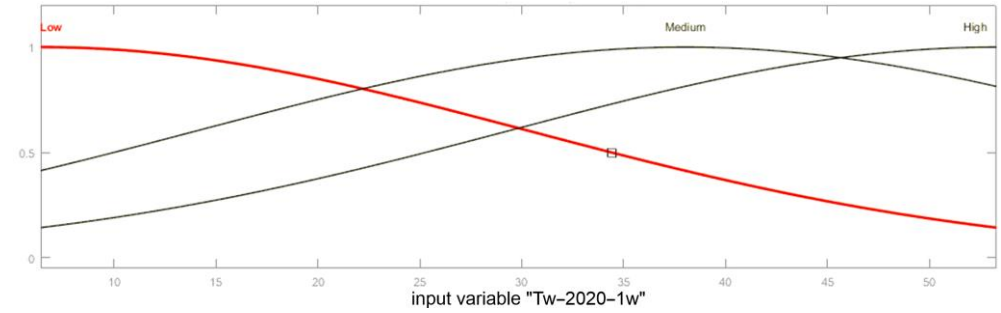
* significance level of 10%; ** significance level of 5%; *** significance level of 1%.



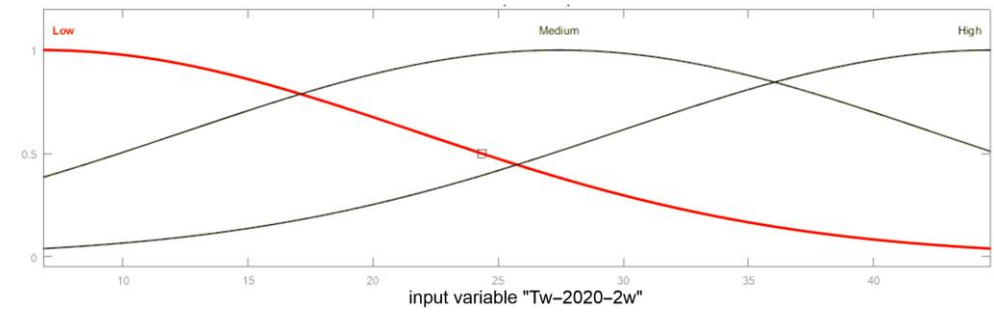

(**a**)




(**b**)




(**c**)




(**d**)

**Figure 7.** Membership function of *GDP growth* (**a**) based on *Tw–es* (**b**), *Tw–1w* (**c**), *Tw–2w* (**d**).

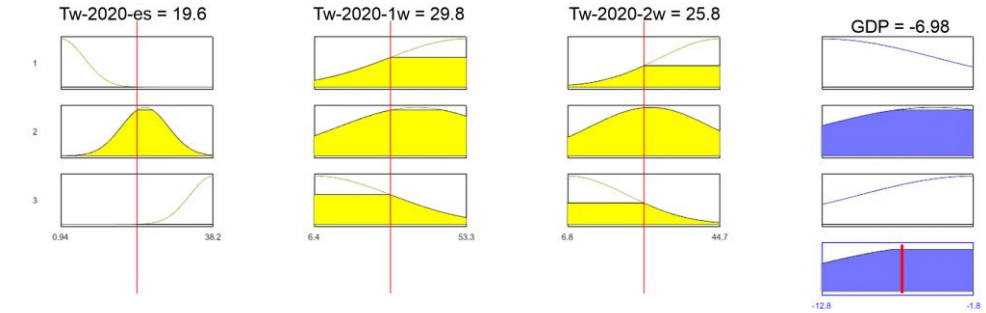
This Gaussian membership function [101] was used due to its normal distribution and because it is similar to human reasoning. For each variable included in the presented models, their distribution for each category is presented as follow:

(i). *Tw–es:* Gaussian distribution [mean; standard deviation]—*Tw–es_low*: [5.69; 0.94]; *Tw–es_medium*: [5.69; 21.48]; *Tw–es_high*: [5.69; 38.20];

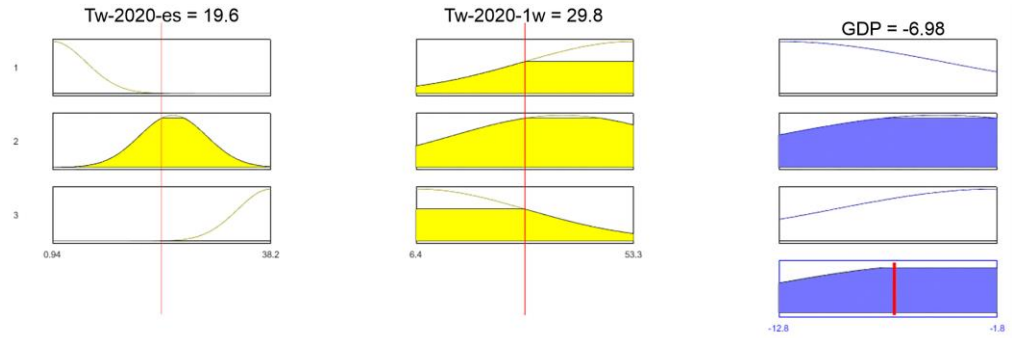
(ii). *Tw–1w:* Gaussian distribution [mean; standard deviation]—*Tw–1w_low*: [23.80; 6.40]; *Tw–1w_medium*: [23.80; 38.00]; *Tw–1w_high*: [23.80; 53.30];

(iii). *Tw–2w*: Gaussian distribution [mean; standard deviation] —*Tw–2w_low*: [14.90; 6.80]; *Tw–2w_medium*: [14.90; 27.40]; *Tw–2w_high*: [14.90; 44.70];
(iv). *GDP*: Gaussian distribution [mean; standard deviation]—*GDP_low*: [−8.30; −12.80]; *GDP_medium*: [−8.30; −4.70]; *GDP_high*: [−8.30; −1.80].

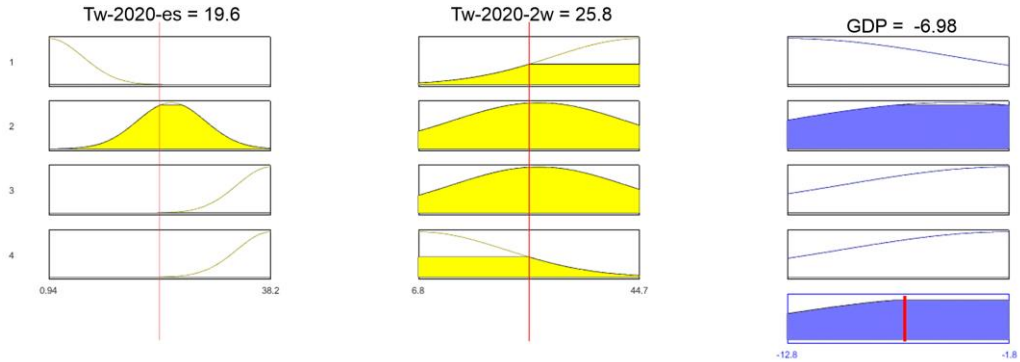
The fuzzy rules, associated ranges, and final output GDP growth (*GDP*) are presented in Figure 8.




(**a**) Fuzzy rules based for FIS model 1




(**b**) Fuzzy rules based for FIS model 2

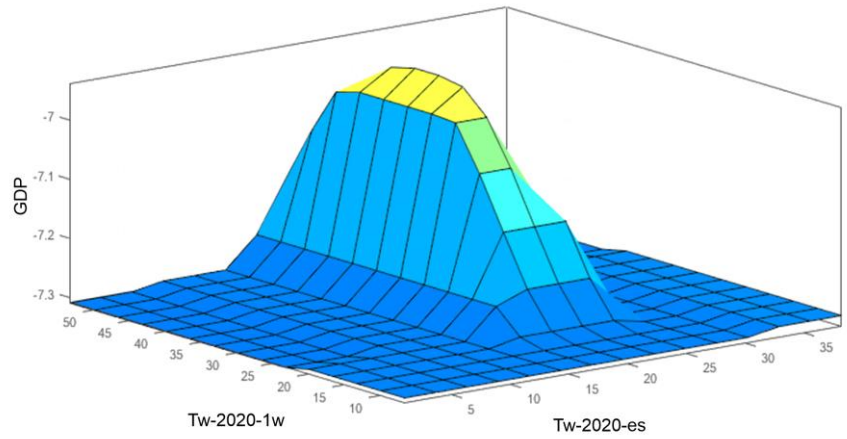



(**c**) Fuzzy rules based for FIS model 3

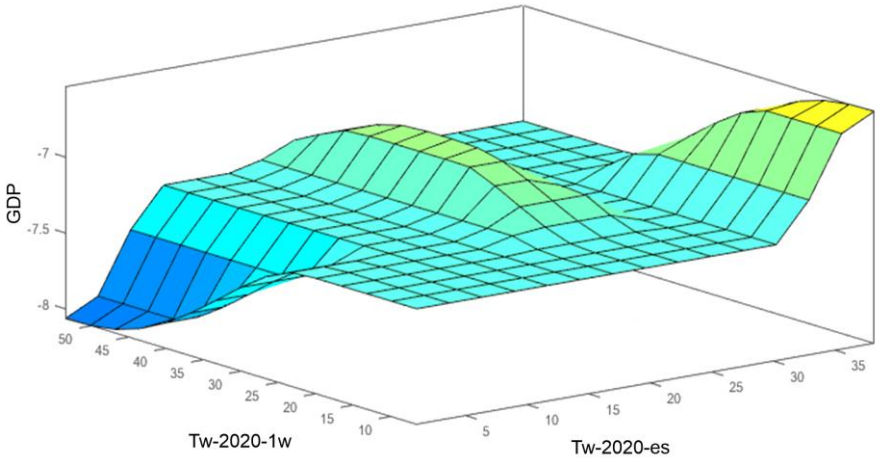
**Figure 8.** The fuzzy rules based for the FIS models 1, 2, and 3.

Figure 8 presents the fuzzified variables associated with the proposed rules in order to obtain the defuzzified output variable, *GDP*. The output variable *GDP* is transformed into a crisp number, with values between −12.80 and −1.80, which could be appreciated as a negative *GDP* variation under the *Tw* influence.

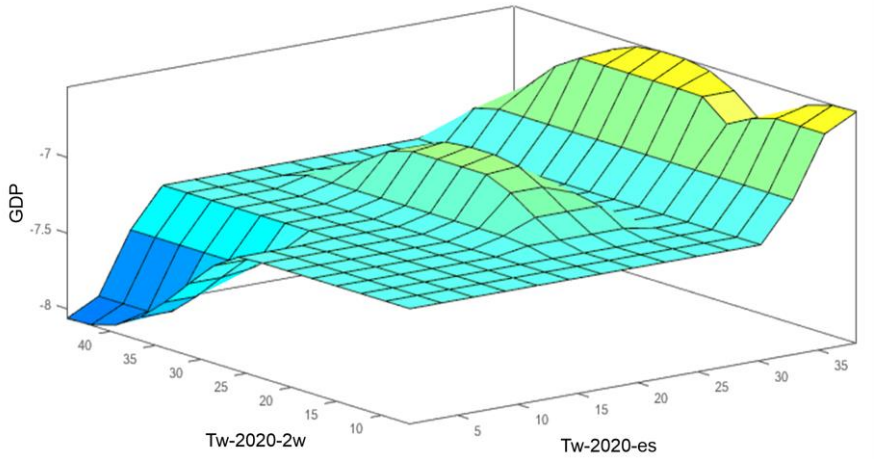
Figure 9 presents the three diagrams associated with the distribution of *GDP* under the influence of *Tw* for FIS models 1, 2, and 3. From the diagram (a), it can be assessed that *GDP* variation is positively influenced by *Tw-es* on the interval [15; 27.5] and by *Tw-1w* on the interval [15; 50]. These results indicate that teleworking has a peak value at 35 for *Tw-1w* and a peak value at 22.5 for *Tw-es* where the maximum value of GDP is −7.




(**a**) GDP for FIS model 1




(**b**) GDP for FIS model 2




(**c**) GDP for FIS model 3

**Figure 9.** Diagrams associated with the distribution of *GDP*.

From diagram (b), it can be observed that *GDP* variation is positively influenced by *Tw-es* on the intervals [20; 27.5] and [32.5; 37.5] and by *Tw-1w* for values on the interval [0; 30]; it is negatively influenced by *Tw-1w* for values greater than 30. Furthermore, these results indicate that teleworking has a peak value at 37.5 for *Tw-es* and a peak value for the interval [0; 10] for *Tw-1w* where the maximum value of GDP is −7.

In diagram (c) from Figure 9, it can be noted that *GDP* variation is positively influenced by *Tw-es* on the intervals [20; 25] and values greater than 30 and by *Tw-2w* for values on the interval [0; 30]; it is negatively influenced by *Tw-2w* for values greater than 30. Furthermore, these results indicate that teleworking has a peak value at 37.5 for *Tw-es* and a peak value at [0; 10] ∪ [20; 30] for *Tw-2w*, where the maximum value of GDP is −7.

## 5. Conclusions

Teleworking is known as a way of the future that enhances economic growth as an accumulation of physical as well as human capital. By using digitalization processes that increase the procedures and services efficiency and reduce the repetitive work of employers by using technology, teleworking improves firm performance by enhancing efficiency, motivation, and knowledge creation.

Relevant studies conducted in the European Union before the COVID-19 pandemic show that only 5.1% of EU residents regularly practiced teleworking [102]. At the EU level, an average score of 10.24 was reported for teleworking, where 0 is the minimum and 100 is the maximum—for the sectors that allow teleworking without negative implications. However, this subject is still debatable due to the unknown implications of teleworking on economic growth, as the telecommuting integration ratio was low until the numerous lockdowns caused by COVID-19 [103]. In these circumstances, the economic effects of social distancing were negative, but the connection with families improved, as shown in the results of the present study, thus confirming the results of Herrera et al. [104] and of Schall and Chen [105].

Teleworking is an activity that should balance the workspace and the family without losing productivity. Access to the Internet and the work value, reflected in salaries and employment, are factors with a positive influence on teleworking. Teleworking allows employees to accomplish job tasks from home or any other places, but not in the office; however, the psychological factor should not be neglected. The consequences can be stress or isolation, so it must be balanced with an improvement of the family relationship.

The research results show that until 2019, Internet access, employment ratio, and the average wage significantly influenced the use of teleworking as an option for employees, without recording any differences between males and females. However, in the pandemic year 2020, the analysis showed some significant differences in using teleworking. In these conditions, the first two lockdowns revealed different patterns.

In the case of the first major lockdown (April–May), the average wage was not a significant variable of interest, while Internet access and the employment ratio had significant influences on teleworking. This might suggest that employees were not really interested in their income, compared with maintaining job security through teleworking offered by Internet access. For the second major lockdown (June–July), only Internet access had a significant influence, while the other variables did not influence the perception regarding teleworking. This might suggest that, given the infrastructure already created in the first wave if not before that, employees took advantage of it and continued, on a lower scale, to keep social distancing, although the measures taken in the second wave were not perceived to be as tough as in the first one.

Based on the obtained results, the two proposed research hypotheses were validated. Using ANOVA procedure, Pearson correlation, and generalized linear regression models, this paper tested the influence of IT infrastructure (measured by Internet access), average wage, and employment ratio on teleworking integration ($H_1$). For the second hypothesis ($H_2$), using generalized linear regression models and fuzzy logic, the influence of teleworking (based on its determinates) on economic growth was estimated in the pandemic context. This fact has resulted in the: (i) estimation and testing of the influence of Internet access, average wage, and employment ratio on the teleworking ratio, considering the total population, but also the division by sex; (ii) estimation and testing of the influence of telework on the GDP growth, considering the total population, but also the division

by sex; and (iii) estimation of GDP growth probability distribution under the influence of teleworking based on a fuzzy logic analysis.

This paper contributes to the literature in several ways. Firstly, it emphasizes the history and role of telework in society by comparing the perspectives of males and females in the topic. The paper offers a profile of the teleworker during pandemic times. Thus, for females, teleworking offered them the possibility of working without neglecting the family, while for males, telework was always an option, the difference being made by the wage. While the males were representative for teleworking in the 2008–2019 period, the COVID-19 pandemic brought female workers who did not want to stop working to the forefront, so that they could use the computer in order to take care of the family and work from home. Secondly, the telework was analyzed as a factor of interest for economic growth. The results show that it is not a solution for improving the GDP growth; however, the circumstances of the COVID-19 pandemic were also notable in drawing this conclusion. Telework was a solution for businesses to continue in the pandemic, but the shock of declining activity due to low consumption and production is reflected in the negative influence of teleworking on GDP growth. Thirdly, the paper offers the possibility of analyzing the evolution of GDP using fuzzy logic.

The research limitations are mainly represented in using the EU context and not the international one, where there were different approaches in using teleworking during lockdowns. In this condition, it would be useful to extend the analysis at the international level, introducing cultural, religion, social, and political factors.

**Author Contributions:** Conceptualization, I.-B.R., I.V.H., D.N.S. and M.V.; investigation, I.-B.R. and R.-M.D.; methodology, I.-B.R., R.-M.D. and I.V.H.; software, I.V.H.; supervision, I.-B.R.; validation, D.N.S. and M.V.; writing—original draft, I.-B.R., R.-M.D. and I.V.H.; writing—review and editing, I.-B.R. and I.V.H. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research received no external funding.

**Institutional Review Board Statement:** This study did not require ethical approval.

**Informed Consent Statement:** Not applicable.

**Data Availability Statement:** All the data provided from public databases.

**Acknowledgments:** This work was supported by a grant of the Romanian Ministry of Education and Research, CNCS—UEFISCDI, project number PN-III-P1-1.1-TE-2019-1642, within PNCDI III.

**Conflicts of Interest:** The authors declare no conflict of interest.

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