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REGULAR ARTICLE

The new industrial revolution: the optimal choice for flexible work companies

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Abstract

The mandatory shift to remote work during the COVID-19 pandemic has made employers and employees increasingly aware of the productivity benefits that may arise from the digital revolution. To explore the characteristics of these gains, we build a model that enables companies to choose from three types of relationship inputs: face-to-face, remote synchronous, and remote asynchronous. Once remote interactions are included, five factors influencing job satisfaction and therefore worker productivity can be identified: (i) reduced mobility, (ii) interaction frequency, (iii) optimal time/place, (iv) work-life balance, and (v) relationship decay effects. We compute the optimal distribution of the three relationship types that maximize corporate profits, conditioning on reasonable parametric assumptions on these five effects. Additionally, we evaluate the potential productivity growth for companies employing only face-to-face interactions when introducing remote interactions. We test our theoretical predictions with a Structural Equation Model, revealing that remote work enhances worker satisfaction and willingness to contribute additional effort at the same wage. Our empirical findings have relevant implications for industrial and environmental policies at both national and supranational levels.

Keywords Flexible work · Remote work · Digital relationship · Productivity · Structural equation model

JEL Classification J24 · O30

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1 Introduction

Flexible and remote work (telework), facilitated by advancements in digital technology, had been in place well before the onset of COVID-19. However, the pandemic became a significant global disruptor as lockdown measures forced a majority of workers worldwide to transition to remote work. The unexpected lockdowns served as an experiment for firms across various industries to explore potential advantages linked to telework, including increased productivity, improved work-life balance, reduced health risks, and lower commuting emissions. The transformation has been so quick that examining the impact of this emerging industrial revolution on corporate productivity remains an ongoing challenge for researchers, companies, and policymakers.

Our article aims to provide an original contribution to this research stream with a theoretical framework that models the distinct characteristics of online and onsite work and simulates firms' decision-making in this context.

In 2020, over one-third of European workers moved to teleworking, and this number was higher in nations more affected by COVID-19 and already endowed with well-established teleworking infrastructure (ILO 2021). Notably, approximately 25 percent of people with no prior experience of remote work adopted telework practices (ILO 2021). In the United States, the impact was probably even higher: workers, on average, increased their remote working time from 5 percent before 2020 to 60 percent in the spring of 2020 (Barrero et al. 2021). Not every job can be performed remotely, though, and telework prevalence may vary significantly across sectors. In Europe, the highest proportion of workers regularly or occasionally using telework (40 percent or more) is found among teaching professionals, information and communication technology professionals, and administrative and commercial managers. In fact, certain occupations, such as clerks and sales workers, find it nearly impossible to transition away from face-to-face interactions, resulting in a teleworking involvement rate of approximately 6 percent in these categories (Milasi et al. 2020).

The COVID-19 led revolution has already changed corporate behavior. Prompted by lockdown policies, several private companies have introduced hybrid contracts for their employees, allowing a combination of in-office and telework activities (see Table 8 in the Appendix). Nevertheless, there is a possibility that certain firms may revert to pre-pandemic working conditions at the present time of removed restrictions. In the current post-pandemic phase many companies are still trying to understand the potential impact of hybrid contracts on costs, labor productivity, and revenues. Our paper aims to contribute to this direction filling a gap in the growing literature on the issue.

In our model, firms aim to minimize costs in producing a specific output quantity using workers' interactions as inputs. We also consider the impact of the digital revolution by assuming that workers possess not fully overlapping skills and can engage in various interaction modes: in-person (e.g., in-office meetings), remote with synchronous interactions (e.g., phone or video calls), or remote with sequential interactions (e.g., instant message or email conversations or shared

documents). These three interaction types, serving as inputs in our model's firm production function, exhibit different costs and benefits attributed to the time and place constraints of in-person meetings, time limitations in remote simultaneous meetings, and the absence of both constraints in remote and sequential interactions. We calibrate our model by incorporating five key attributes of remote work associated with time and space constraints, influencing costs and benefits and therefore the final job satisfaction: (i) reduced mobility, (ii) interaction frequency, (iii) optimal time/place, (iv) work-life balance, and (v) relationship decay effects.

A distinctive feature of our model is the redefinition of the conventional micro-economic production function in terms of human relationships and interactions. Here, we acknowledge that contemporary corporate productivity is largely contingent on the execution of complex tasks that require interactions, information exchange, and collaborative efforts among multiple employees endowed with complementary non-overlapping skills. Consequently, individual workers operating in isolation are unable to generate any output, reflecting the framework of our model. While labor and capital continue to be key components in production, a comprehensive exploration of the role and significance of workers' interactions is imperative in this respect.

The theoretical insights from our model illustrate how the optimal distribution of the three types of interactions evolves with changes in assumptions on costs and productivity. With reasonable parameters, under the assumption that remote interactions incur 15 percent lower costs and enhance worker productivity by 20 percent, firms should ideally allocate approximately 26 percent to in-person meetings, 32 percent to remote simultaneous meetings, and 41 percent to remote sequential interactions. Remarkably, this allocation results in nearly 17 percent lower total costs while maintaining a constant total number of interactions. Our estimates reinforce the notion that remote work enhances productivity, particularly in scenarios where offices are expected to be crowded, and employees are engaged in the public sector.

In the empirical part of our paper, we validate our theoretical predictions through a structural equation model using data from the European Social Survey (ESS). In this section we demonstrate that remote work improves both worker satisfaction and their willingness to contribute additional effort at the current wage highlighting potential for win-win corporate and government policies related to productivity and job satisfaction.

The remainder of the paper is organized as follows. In Sect. 2 we review the main literature our analysis is grounded on. Section 3 introduces the benchmark model. Sections 4 and 5 present simulations under different cost and productivity scenarios, illustrating how the optimal number of cost-minimizing interactions of the three types change. In Sect. 6, we empirically test our theoretical findings using a structural equation modeling (SEM) approach, examining how remote work encourages workers to undertake extra unpaid work by enhancing their life satisfaction. Section 7 discusses how corporate governance and policymakers can derive benefits from our analysis, along with the limitations they should consider. Finally, Section 8 provides concluding remarks.

2 Literature review

The scholarly debate concerning the interplay among telework, corporate profits, and productivity is partially developed, as it predominantly relies on surveys and case studies that lack rigorous theoretical and empirical approaches, particularly after COVID-19. In this respect, several surveys suggest that telework is associated with higher perceived productivity (Harker Martin and MacDonnell 2012; Bloom et al. 2015; Giovanis 2018; Barrero et al. 2021 also see Kosteas et al., 2022 for an extensive review). In a randomized experiment involving 249 call center operators, Bloom et al. (2015) demonstrated that individuals working from home outperformed their in-office counterparts by 13 percent, both in terms of hours logged into the system and number of calls taken per minute. Subsequent interviews revealed that this outcome was attributed to the increased convenience of working from home, the reduced stress of home environments, and elevated job satisfaction. More recently, Nakrosiene et al. (2019) and Gallardo and Whitacre (2018) reported similar findings, exploring the impact of telework on local economies and highlighting increased worker satisfaction and productivity, consequently contributing to an increased median income level.

Further analysis suggests that the relationship between telework and productivity is not strictly linear. Hoornweg et al. (2016) discovered that productivity might be higher when telework intensity is low, while Felstead and Henseke (2017) revealed that benefits associated with remote work, such as increased organizational commitment, job satisfaction, and job-related well-being, come at the expense of a higher difficulty in disengaging from work. Other empirical analyses find no significant effects of telework on productivity, with similar proportions of employers reporting increased and decreased productivity (Boys 2020, Russo et al. 2021).[1]

As expected, the research activity focused on working from home and its impact intensified during COVID-19. Findings from this literature are not unequivocal, though. Several studies highlight a significant and positive correlation among work-life balance, job satisfaction, and productivity (Saba et al. 2020; Ravi and Anulakshmi 2021; Arkesteijn et al. 2021), particularly when remote work is facilitated by enhanced broadband connections and communication technologies (Kniffin et al. 2021). According to a survey conducted by GitLab (2020) involving 3,000 professionals in the information and technology sector working remotely, over half of the employees experienced reduced travel and reported increased productivity and efficiency. Conversely, certain studies have documented a negative impact of working from home during the lockdown on productivity (Rubin et al. 2020; Gibbs et al. 2021). These declines in productivity may be attributed to the exceptional circumstances of the lockdown, where many companies were not fully prepared to transition all their operations online, and working parents found themselves sharing their home offices with children. Indeed, heightened communication and coordination costs, reduced intra- and inter-unit communications, and the presence of children at

[1] See also CIPD (2020).

home are all factors contributing to increased work hours and decreased productivity (Gibbs et al. 2021).

Consequently, these adverse changes in productivity are likely associated with the unique challenges posed by lockdown measures and may not represent ordinary working conditions, where employers and employees have already payed the fixed costs of being well-equipped.

A comprehensive systematic review by Anakpo et al. (2023) tries to sum up the existing evidence on the impact of a Work-From-Home model on employee productivity and performance. The authors show that productivity varies based on factors such as the nature of work, employer characteristics, and home settings. The review reveals that the majority of participants reported a positive impact, while only a few observed no difference or a negative effect. The study recommends improving technology and information and technology training to enhance productivity, especially for those considering its adoption beyond the pandemic.

Overall, the empirical literature on the effect of telework agrees on the necessity for a robust theoretical framework to model firms' decisions regarding telework conditions. Such a framework would encompass various factors influencing the relationship between telework and corporate productivity, enabling the simulation and assessment of their respective impacts. Our paper aims to make a substantial contribution to this body of literature along this line. We acknowledge that the digital revolution and its full potential revealed by the forced telework during COVID-19 made clear how the three types of interactions represent production inputs. We introduce a theoretical model focused on optimizing employers' interactions and a structural equation model that empirically tests our theoretical predictions on job satisfaction and productivity.

Our analysis originally advances the scholarly debate on several fronts. A first contribution is to the Social Exchange Theory (Miller, 2019) applied to telework. This literature shows that workers, when having the flexibility to choose their work environment, tend to make sacrifices, such as increased effort, as a demonstration of commitment to both the employer and colleagues (Golden, 2007; Kelliher and Anderson, 2010; de Menezes and Kelliher, 2011; Elsbach et al., 2012). The Social Exchange Theory hinges back on the gift exchange literature (Akerlof 1982 and Akerlof 1984). Workers' gratitude for a *gift* from employers consists in reduced turnover, reduced shirking and higher effort including unpaid extra hours, provided that the employer-worker relationship triggers workers intrinsic motivations. Up to the extreme emphasized by Freeman (1997) who points out that volunteers are so intrinsically motivated to "work for nothing." Between the extremes of volunteers and quiet shirkers doing the minimum to keep their jobs there are a lot of intermediate situations where intrinsically motivated workers can work unpaid extra hours. More specifically to our case of remote work, employees' gains, resulting from the potential for achieving a better work-life balance can increase job satisfaction and organizational commitment. We posit that this *gift exchange* represents a primary source of increased productivity, seen as a reflection of employees' gains. The recent literature confirms gains arising from an improved work-life balance, consequently enhancing job satisfaction and organizational commitment (Sardeshmukh et al. 2012, Wheatley, 2012). To analyze in depth this phenomenon we devise a model

that strongly considers the mediating effect of job satisfaction, resulting from teleworking, on productivity (Shobe 2018; Davidescu et al. 2020; Hashim et al. 2020; Abilash and Siju 2021; Subing and Waskito 2023). Our theoretical win-win predictions on jobs satisfaction and productivity need to be compared with alternative views. More specifically, in accordance with the theory of "borders", in a remote setting, workers might struggle to disconnect, experiencing a reduction in real-life interactions (Clark, 2000: 751). Unclear boundaries between home and work environments, as it often occurs in remote work, amplify work pressures, impeding the ability to "switch off" and relax.

Border theory predicts increased negative work-home spill-overs in remote work, supported by qualitative studies (Mirchandani 2000). In our model, we analyze both factors that contribute to increased (productivity gains) or decreased (cost) job satisfaction, consequently influencing the overall variations in total productivity.

3 The benchmark model

We model the firm's operational framework using a three-factor constant elasticity of substitution (CES) production function, where workers' interactions represent the only production inputs. We consider only those occupations suitable for remote or flexible work arrangements and three distinct types of interactions:

- *Face-to-face synchronous (F2F) interactions*: These interactions need participants to share the same physical space and time allocation, implying common place and simultaneous time constraints.
- *Remote synchronous (RS) interactions*: These interactions require a technology that enables virtual meetings, with participants possibly being in different locations. The only constraint is simultaneous time.
- *Remote asynchronous (RA) interactions*: These interactions involve the use of technology for remote and sequential communication, such as email or messaging services. This type allows for the elimination of both common place and simultaneous time constraints.

Our model diverges significantly from the well-known industry world represented in the comedy "Modern Times" by Charlie Chaplin, where production relies on individual workers interacting with machines and operating under hierarchical supervision. In our model, the company resembles a collaborative environment where production and productivity gains are obtained through interactions among workers. In the absence of interactions, there is no production, emphasizing the indispensable role of interactions in generating positive output. This contrasts with the traditional assembly-line model, where individual workers can contribute to production independently.

More formally, we denote by Y the total output, $X_i, i, = 1, 2, 3$ the number of interactions of F2F, RS and RA, respectively, $a_0 > 0$ the total factor productivity and a_i the output elasticity the three types of interactions, respectively. Under such

assumptions, the productivity of the interaction of workers firms produces a given amount of quantity according to the general CES production function.

$$Y(X_i) = a_0\left(\sum_{i=1}^{n} a_i X_i^{-\rho}\right)^{-\frac{1}{\rho}} \tag{1}$$

where $\rho > -1$ is the parameter associated with the elasticity of substitution, $a_i \geq 0$ and $X_i \geq 0$.

In this way, we take into account the possibility that the work organization does not utilize RS or F2F interactions ($X_i = 0$ for $i = 1$ or $i = 2$ and $X_i > 0$ for $i = 3$).

In fact, certain digital business models prove to be more efficient precisely because they operate without physical offices, relying solely on (RS) and (RA) interactions. Our extended conceptual framework assumes that the final output depends on the interactions among these different forms of engagement. In cases where there is one type of interactions only, the end product is solely the result of the activities within that framework.

Given our focus on the three forms of work, we start by assuming that $X_i > 0$ are all positive (case I). Since these inputs involve the same workers, it is reasonable to expect high substitutability among them. Consequently, as is well known, a CES with very high substitutability among factors may be represented by a Cobb–Douglas technology (i.e., with $\rho \to 0$). Therefore, for simplicity and without lack of generality, we can use a Cobb–Douglas production function with the additional assumption on what happens when one of the inputs is zero.[2] Lastly, to better compare how productivity increases in companies that have never adopted remote work, we then analyze the scenario where only face-to-face interactions are at work.(case II). Therefore we focus only on cases I and II in the rest of the paper.

3.1 A company with three distinct types of interactions (case I)

In the case of a company with three distinct types of interactions, worker productivity generates a specified quantity according to the following Cobb–Douglas production function:

$$Y = f(X_1, X_2, X_3) = a_0 X_1^{a_1} X_2^{a_2} X_3^{a_3} \quad \text{with} \quad X_1, X_2, X_3 > 0 \tag{2}$$

To emphasize the dependency between the elasticities of factor inputs and productivity, we refer to factors a_i, for $i = 1, \ldots, 3$, and for simplicity, we also assume

[2] We think that a Cobb-Douglas technology is the most suitable function for our analysis as it is often employed to measure the product of three production factors due to its effective representation of the interrelation among them. Its mathematical form allows to capture the multiplicative effect of these factors and show how simultaneous variations in the factors influence the final production. This characteristic makes the Cobb–Douglas technology the most suitable function to analyze the dynamics between production factors and their combined impact on overall output. The detailed approach of the Cobb–Douglas provides an in-depth understanding of production dynamics, demonstrating how production factors interact and contribute to total output.

constant marginal return to scale, that is, $a_1 + a_2 + a_3 = 1$, and we refer to interaction F2F, RS, and RA, as interaction 1, 2, and 3, respectively.

The Cobb–Douglas production function assumes that inputs are not perfect substitutes, i.e., firms need at least a small amount of all types of interactions.

3.1.1 Cost minimization

The productive units of our model aim to minimize their costs, that is they solve the following cost minimization problem:

$$\min_{X_1,X_2,X_3} \quad c_1X_1 + c_2X_2 + c_3X_3 \quad \text{s.t.} \qquad Y = a_0X_1^{a_1}X_2^{a_2}X_3^{a_3} \tag{3}$$

where c_1, c_2, and c_3 are the marginal costs of the three interactions.

The Lagrangian of the cost minimization problem can be written as

$$L(c_1, c_2, c_3, X_1, X_2, X_3, Y) = c_1X_1 + c_2X_2 + c_3X_3 + \mu(Y - a_0X_1^{a_1}X_2^{a_2}X_3^{a_3})$$

and its solution leads to the following system of first-order conditions

$$\begin{aligned}
L_{X1} &: \quad c_1 = \mu a_0 a_1 X_1^{(a_1-1)} X_2^{a_2} X_3^{a_3} \\
L_{X2} &: \quad c_2 = \mu a_0 a_2 X_2^{(a_2-1)} X_1^{a_1} X_3^{a_3} \\
L_{X3} &: \quad c_3 = \mu a_0 a_3 X_3^{(a_3-1)} X_1^{a_1} X_2^{a_2} \\
L_{\mu} &: \quad Y - a_0 X_1^{a_1} X_2^{a_2} X_3^{a_3} = 0
\end{aligned}$$

The optimal solutions as a function of total output, total factor productivity, and interactions between productivity and costs can be written as

$$\begin{aligned}
X_1^* &= \left(\frac{Y}{a_0}\right)\left(\frac{a_1}{c_1}\right)^{a_2} + a_3\left(\frac{c_2}{a_2}\right)^{a_2}\left(\frac{c_3}{a_3}\right)^{a_3} \\
X_2^* &= \left(\frac{Y}{a_0}\right)\left(\frac{a_2}{c_2}\right)^{a_1} + a_3\left(\frac{c_1}{a_1}\right)^{a_1}\left(\frac{c_3}{a_3}\right)^{a_3} \\
X_3^* &= \left(\frac{Y}{a_0}\right)\left(\frac{a_3}{c_3}\right)^{a_1} + a_2\left(\frac{c_1}{a_1}\right)^{a_1}\left(\frac{c_2}{a_2}\right)^{a_2}
\end{aligned}$$

and the total cost as

$$\begin{aligned}
C := \left(\frac{Y}{a_0}\right)\Bigg(c_1\left(\frac{a_1}{c_1}\right)^{a_2} + a_3\left(\frac{c_2}{a_2}\right)^{a_2}\left(\frac{c_3}{a_3}\right)^{a_3} + c_2\left(\frac{a_2}{c_2}\right)^{a_1} + a_3\left(\frac{c_1}{a_1}\right)^{a_1}\left(\frac{c_3}{a_3}\right)^{a_3} \\
+ c_3\left(\frac{a_3}{c_3}\right)^{a_1} + a_2\left(\frac{c_1}{a_1}\right)^{a_1}\left(\frac{c_2}{a_2}\right)^{a_2}\Bigg)
\end{aligned} \tag{4}$$

This is the minimum cost given that total output produced by the firm is Y.

Comparative statics on optimal choices of the three types of interaction show that they depend positively on their own productivity (that is, $a_i, i = 1, \ldots, 3$) and

negatively on their own cost (that is, c_i). They also depend negatively on productivity of the other types of interactions and positively on the costs of other types of interactions.

3.1.2 Drivers of job satisfaction: benefits and costs of the three interactions

In the rest of the model, we outline five key factors that can explain differences in costs (c_1, c_2, c_3) and productivity gains for the three types of interactions.

3.1.3 Factors enhancing job satisfaction

Commuting (g): The elimination of commutes in remote work not only saves time but also reduces costs for both employers and employees. Employers can experience a reduction in office-related expenses such as rent, maintenance, and energy bills. It is important to note that the cost-saving benefits can be distributed between the employer and the employee, a topic we address in the discussion section, exploring how employers can share this benefit with their workers. Additionally, for workers engaging in RS interactions, physical presence in the same location is not required, and the need to synchronize schedules is eliminated with RA interactions. This results in time and cost savings associated with commuting, making RA and RS interactions more productive and cost-effective.

We call g_1, g_2 and g_3 the firm's monetary gain due to lower cost associated to F2F, RS, and RA interactions, respectively. Then, we have that

$$g_1 < g_2 \leq g_3$$

where the first inequality represents higher gains for firms if workers meet remotely, and the second weak inequality captures the idea that RA can be even cheaper than RS, e.g., through cheaper technology required and pecuniary benefits of no need of time synchronicity. Taking into account these gains, costs for firms can be written as

$$c_1 > c_2 = c_1 - \frac{g_2 - g_1}{g_1} \geq c_3 = c_1 - \frac{g_3 - g_1}{g_1}$$

that is, the cost of RS and RS is discounted by their respective percentage gain, expressed in terms of monetary gain for F2F meetings.

Frequency of interactions (k): Remote work activities not only save time and money, such as reduced commuting and improved space/time allocation, but they also enable more frequent interactions due to a more efficient use of time. We call this productivity gain for the F2F, RS and RA interactions k_1, k_2, and k_3, respectively, and then we have

$$k_1 < k_2 < k_3$$

Optimal time/place (v): Remote work, especially with remote asynchronous (RA) interactions, provides workers the flexibility to choose the optimal time and space for their tasks. This may increase productivity as it allows workers to work under their most favorable conditions, overcoming limitations related to time and space.

The flexibility extends beyond geographical constraints, as RA interactions enable workers to allocate their time and space based on individual preferences and productivity hours. Factors such as variations in work habits, sleeping patterns, and personal circumstances can influence the optimal working hours for different individuals. For example, those who are more productive in the morning can schedule activities accordingly. Additionally, RA interactions facilitate the use of messaging services, enabling team members to stay updated even when only a subset is actively engaged. This accelerates the exchange of ideas and information within the team.

From a theoretical point of view, we therefore model the optimal time-place effect by calling v_1, v_2 and v_3 the additional productivity arising from F2F, RS, and RA on this dimension, respectively, and assume

$$v_1 < v_2 < v_3$$

Work-life balance (w): The hybrid model with lower commuting and greater flexibility may lead to reduced distress and improved health conditions for workers. This positive impact on well-being, particularly evident in remote asynchronous (RA) meetings, stems from the removal of both place and time constraints in these interactions. The effect on work-life balance is more pronounced in RA meetings compared to remote synchronous (RS) meetings, where only the place constraint is relaxed. We argue that work-life balance increases the quality of workers' interactions and productivity, and conveniently assume that

$$w_1 < w_2 < w_3$$

where w_i is the productivity gain arising from e better work-life balance for each interaction $i = 1, 2, 3$.

3.1.4 Factors reducing job satisfaction

Relationship decay (p): For all the reasons described above remote interactions contribute to increased employee productivity, at the cost, however, of reducing the quality of relationships among employees. This reduction is primarily attributed to the absence of the richness of non-verbal and informal communication, which is highly valuable for building strong relationships. Remote meetings, lacking some or most of these aspects, may fall short in fostering the depth of connections typically achieved through face-to-face interactions. As a response to this challenge, emoticons, commonly used in messaging during remote interactions, have been developed to compensate for the absence of nuanced non-verbal cues. In this respect, Bicchieri and Lev-On (2007) resume the experimental game theoretical literature in social dilemmas and show that F2F communication facilitates a focus on pro-social norms, making it easier to achieve positive outcomes compared to interactions mediated by web sources. Xiao and Houser (2005) posit that the increased likelihood of expressing emotions in F2F interactions raises incentives for pro-social behavior. Supporting this, evidence from studies such as Becchetti et al. (2021) and Geraci et al. (2022) indicates that

Table 1 Factors affecting costs and productivity and assumptions on their parameters

Productivity factor	Parameters	Impact	Model parameters
Commuting	g1 > g2 > g3	Monetary cost	c1 > c2 = c1 – (g2-g1)/g1 > c3 = c1 – (g3-g1)/ g1
Frequency of interactions	k1 < k2 < k3	Productivity gain (k)	a1 = 4 / (12 + k + v + w – p) a2 = 1 / 3a3 = 4 / (12 + 2k + 2v + 2w – 2p)
Optimal time/place	$v_1 < v_2 < v_3$	Productivity gain (v)	
Work-life balance	$w_1 < w_2 < w_3$	Productivity gain (w)	
Relationship decay	$p_1 < p_2 < p_3$	Productivity loss (p)	

Model parameters assume costs and productivity gains and losses are constant for RS and RA meetings and they are meant to be expressed as percentage change from the unitary measure under F2F meetings.

Table 2 Calibration of the model (homogeneous costs)

(productivity gain, relationship decay)	F2F	RS	RA	Total no. meetings	Share of RA
(0,0)	30	30	30	90	0.33
(15,5)	29.26	29.99	30.73	89.98	0.34
(30,5)	28.20	29.97	31.73	89.90	0.35
(30,10)	28.55	29.98	31.40	89.93	0.35
(45,5)	27.20	29.92	32.64	89.75	0.36

F2F = face-to-face; RS = remote synchronous; RA = remote asynchronous; total factor productivity (a_0) = 1; Meetings costs (c_1, c_2, and c_3) = 1; Output (Y) = 30; Productivity parameter for F2F meetings (a_1) = 400/(1200 + k + v + w – p). Productivity gains are assumed to be homogeneous, i.e., k = v = w

spending more time on the web or having a better broadband connection is associated with a reduction in social capital. Remote interactions may also reduce the quality of relationships at home because in a remote setting, workers might struggle to disconnect, experiencing a reduction in real-life interactions, as predicted by the "Theory of Borders" (Clark 2000), decreasing workers satisfaction.

For each type of interaction $i = 1, 2, 3$, representing F2F, RS, and RA, respectively, we define the relational penalty p_i and we assume $0 = p_1 < p_2 < p_3$.

In essence, there is no relational penalty associated with F2F interactions, while the penalty is highest when interactions are asynchronous. We also consider that the term p may encompass other costs detrimental to productivity, including diminished concentration in home settings, digital infrastructure, uncomfortable remote working environments, or caregiving responsibilities.

Based on what we considered above, each interaction i is characterized by some marginal costs $c_i(g_i)$, which depend on the commuting factor g_i, and on the

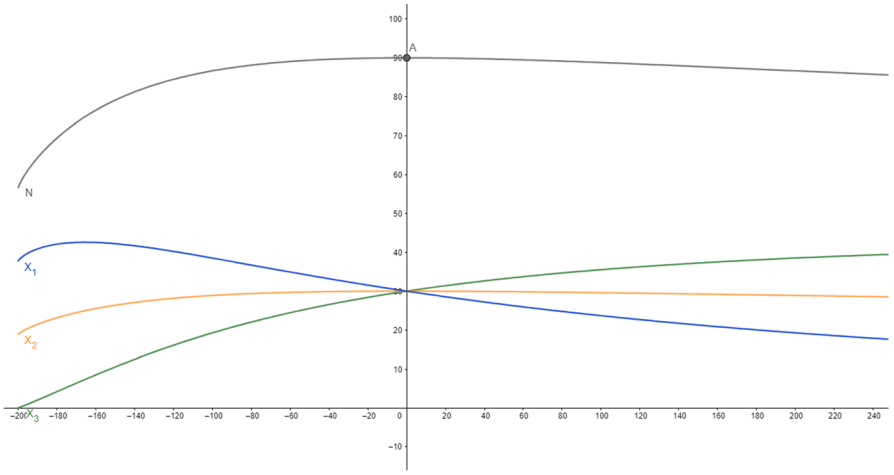

Fig. 1 Calibration of the model. *Notes*: Vertical axis: number of interactions. Horizontal axis: difference between overall productivity gain and relationship decay (k + v + w − p). Grey line: total number of interactions; Blue line: face-to-face interactions; Yellow line: remote synchronous interactions; Green line: remote asynchronous interactions (color figure online)

productivity factors $a_i(k_i, v_i, w_i, p_i)$. The combination of the frequency of interactions, optimal time/place working slot, and work-life balance effects orders the three interaction types such that RA is more productive than RS, and RS is more productive than F2F, i.e., $a_3 > a_2 > a_1$. On the cost side, however, the mobility reduction and the relationship deterioration effect act in opposite directions and therefore do not allow in principle to establish a clear-cut ranking.

To compute the optimal number of interactions, we assume productivity gains are constant, that is

$$
\begin{aligned}
k &:= k_i - k_j \\
v &:= v_i - v_j \\
w &:= w_i - w_j \\
p &:= p_i - p_j
\end{aligned}
$$

for $i = 2, 3, \quad j = 1, 2, \quad \text{e} \quad i > j$

4 Optimal number of meetings under different scenarios

In our model employers use the cost minimization problem to determine the optimal count of F2F, RS, and RA meetings for their employees. It is essential to recognize that these numbers are highly contingent on various assumptions.

4.1 Varying productivity gains

To examine the impact of productivity gains on the number of meetings, we assume uniform unit costs for each meeting and set unit total factor productivity. This assumption aligns with the conditions observed in major European economies, the US, and Japan, as demonstrated by Calcagnini et al. (2021). Additionally, we establish the output at 30, reflecting the monthly production equivalent to one meeting per day for each meeting type under the condition that all meetings have identical productivity (i.e., $a_1 = a_2 = a_3 = 1/3$ and $X_1 = X_2 = X_3 = 30$, resulting in $Y = 30$) (Table 1).

To figure out how the optimal level of RSE interactions changes as a result of the trade-off between productivity gains and relationship decay, we assume that the level of production, the total factor productivity parameter, and costs are all equal and normalized to one. The output elasticities for each type of interaction are obtained as the share of productivity arising from each type of interaction out of the total productivity.

Table 2 shows the number of Face-to-Face (F2F), Remote Synchronous (RS), and Remote Asynchronous (RA) interactions that minimize firms' costs while maintaining constant production for various values of productivity gains (determined by the sum of the four factors that enhance productivity in remote relationships) and relationship decay. Notably, while the number of RS meetings remains nearly constant, the number of RA meetings rises as the expenses of F2F meetings increase with greater productivity gains. Interestingly, the overall number of meetings decreases. Although this decrease is minimal, it is crucial to recognize that the introduction of remote meetings does not lead to a rise in the total number of meetings; rather, there is a reduction, albeit small. In a larger-scale context, such as when the volume of meetings is higher and over a more extended period, this reduction could impact both management and employee satisfaction.

In Fig. 1, we illustrate the number of interactions for Face-to-Face (F2F - blue), Remote Asynchronous (RA - orange), Remote Synchronous (RS - green), and the total interactions (gray) against the difference between the overall productivity gain and the decay of the relationship (i.e., $k + v + w - p$). As indicated in Table 1, we observe that, as long as the net productivity gain is positive and increasing, the number of RS interactions also increases, reflecting a higher gain in productivity relative to the decay of the relationship. This trend continues until a maximum number of RA interactions, although, with our imputed values, this is extremely high. Conversely, the total number of interactions is a decreasing function of the positive net productivity gain (black line), even as the number of RA interactions increases.

In contrast, if the relationship decay effect is significantly greater than the productivity gain (in our example, the difference is -200 on the horizontal axis), the firm finds it no longer profitable to use RS interactions.

If we assume that RA interactions have lower costs than other types of interactions, we observe a higher number of RA interactions for the same productivity difference, reaching the maximum at a lower difference (see Fig. 2).

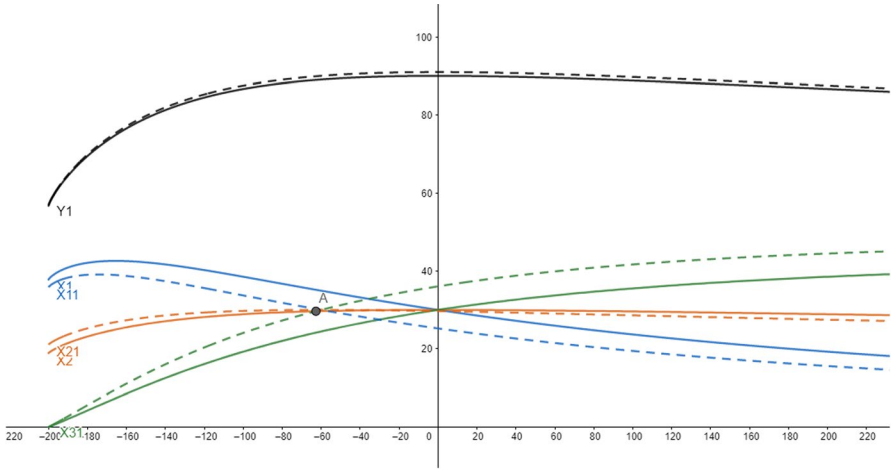

Fig. 2 Number of interactions with different marginal costs. *Notes*: Vertical axis: number of interactions. Horizontal axis: difference between overall productivity gain and relationship decay (k + v + w−p). Grey lines: total number of interactions; Blue lines: face-to-face (F2F) interactions; Yellow line: remote synchronous (RS) interactions; Green lines: remote asynchronous (RA) interactions. Solid lines assume marginal costs are all equal to 1; Dashed lines assume marginal costs are $c_1 = 1$ for F2F interactions, $c_2 = 0.85$ for RS interactions, and $c_3 = 0.7$ for RA interactions (color figure online)

Table 3 Calibration of the model (heterogeneous costs)

(productivity gain, relationship decay)	F2F	RS	RA	Total no. Meetings	Share of RA
(0,0)	25.23	29.69	36.05	90.96	0.40
(30,10)	23.88	29.50	37.52	90.89	0.41
(− 5,5)	25.95	29.77	35.22	90.94	0.39

F2F = face-to-face; RS = remote synchronous; RA = remote asynchronous; total factor productivity (a0) = 1; Meetings costs: c1 = 1, c2 = 0.85, and c3 = 0.7; Output (Y) = 30; Productivity parameter for f2f meetings (a1) = 400/(1200 + k + v + w – p). Productivity gains are assumed to be homogeneous, i.e., k = v=w

4.1.1 Varying costs

Another crucial parameter influencing the decision to work more or less remotely is the marginal cost. Previously, we assumed an identical unit marginal cost for each type of interaction. However, an alternative assumption is that remote interactions have lower marginal costs compared to face-to-face interactions, particularly when a significant portion of costs originates from office-related expenses.

Table 2 presents values simulated with heterogeneous costs (i.e., $c_1 = 1, c_2 = 0.85$, and $c_3 = 0.7$). It is observed that the total number of meetings remains nearly constant, as in the previous case. The proportion of RA meetings is now higher, indicating the efficiency gained through cost reduction. Assuming no differences in productivity, firms would need to implement approximately six more RA interactions and five fewer F2F interactions to minimize costs while keeping RS interactions constant (Table 1, first row). We have also explored a scenario where there is no productivity gain, assuming that productivity might decrease during remote interactions. Even in this case, the share of RA interactions remains higher than that of other interactions (i.e., 0.39), surpassing all previously simulated scenarios in Table 1.

The global dynamics are depicted in Fig. 2, where solid lines represent the number of interactions with uniform costs and dashed lines interactions with varied costs. Notably, the net productivity gain needed to make the number of RA interactions equal to the number of F2F interactions is now negative and non-negligible in magnitude based on our simulated values (approximately -60 at point A). This implies that the disparity between productivity gains and relationship decay must be less than -60 for F2F interactions to prevail in business, whereas with homogeneous costs, this value was 0.

5 Comparison with a fully F2F firm (case II)

We now consider the scenario of a benchmark firm that restricts remote meetings, thus relying solely on F2F interactions to determine its production function. In this context, a critical assumption is the presence of constant returns to scale. This assumption can take two forms. Firstly, we may assume constant returns to scale when only one type of interaction (F2F) or two types (F2F and RS) are applicable, indicating that these interactions are inherently more productive than in our benchmark model. Alternatively, we could assume that interactions maintain the same productivity factors as in the benchmark (i.e., 1/3), leading to a scenario where production exhibits decreasing returns to scale.

Table 3 illustrates the performance of firms in the absence of RA interactions. Assuming the productivity for F2F interactions remains at 1/3, the minimum number of meetings required to maintain the same production level ($Y = 30$) is 2700, significantly higher than the total number of interactions in our benchmark model (90, as shown in Table 1, first row). Even if we assume that the productivity of F2F interactions is twice that of the benchmark, the number of interactions remains much larger (164). Considering all meetings have unit costs, this implies that firms' costs are higher than in the benchmark model, and this cost difference amplifies if we reasonably assume that remote interactions cost less than F2F interactions. Notably, even with two types of interaction having the same productivity as in the benchmark model (i.e., one third each), number of interactions is still substantially higher (332.56 vs. 90).

Table 4 Cost minimisation comparison between a 100% F2F firm and a F2F/RS firm. (a_0=1,Y=30)

Costs		Productivity		CRS	X1	X2	Total meetings	Total costs
1	2	a1	a2					
Only f2f								
1		0.33		0.33	27,000		27,000	27,000
1		0.66		0.66	164.32		164.32	164.32
1		1		1	30		30	30
Only f2f and rs								
1	1	0.33	0.33	0.66	164.32	164.32	328.63	328.63
1	1	0.5	0.5	1	30	30	60	60
1	0.85	0.33	0.33	0.66	151.49	181.07	332.56	305.4
1	0.85	0.5	0.5	0.66	27.66	33.06	60.71	55.76

6 Empirical analysis

In this section, we aim to empirically test our theoretical findings regarding the advantages for employers stemming from a remote work related enhanced workforce productivity, viewed as a reflection of employees' gains, correlated with heightened organizational commitment, job satisfaction, and job-related well-being.

Recent findings from Felstead and Henseke (2017) provide evidence that remote work benefits both employers and employees, contributing to the evolving nature of work in the twenty-first century. Using data from the European Social Survey (ESS), this study presents evidence that remote workers exhibit higher effort compared to their office-based counterparts. Specifically, 24 percent of respondents reported working beyond formal hours and contributing significantly more voluntary effort. Their empirical findings reveal that remote workers' three types of work commitment (extended work hours, higher hourly intensity, and increased voluntary unpaid working hours) are significantly higher than those of identical office-based workers. In our empirical analysis, we also incorporate a variable measuring voluntary unpaid work from the ESS dataset. Addressing concerns about the potential drawbacks of transitioning from home to work, we estimate the indirect effect of job satisfaction.

The underlying idea of our estimates is that, according to our theoretical predictions, remote work increases job satisfaction, and consequently, workers are more productive because they are happier and willing to work more, even accepting unpaid hours. However, as we have seen in our model, according to the "Theory of Borders," it is not guaranteed that they work better, e.g., they might work more simply because, in a remote setting, they struggle to disconnect. We attempt to address this issue by estimating, through Structural Equation Modeling (SEM), not only the direct effect of remote work on unpaid work (surplus work) but also an indirect one through job satisfaction. The underlying assumption is that if workers are happier, they will perform better, not only in terms of quantity

Table 5 Variable legend

High communication	(0/1) dummy variable taking value one if workers communicate with line managers or colleagues once a day or more
Medium high communication	(0/1) dummy variable taking value one if workers communicate with line managers or colleagues several times a week
Medium communication	(0/1) dummy variable taking value one if workers communicate with line managers or colleagues several times a month
Medium low communication	(0/1) dummy variable taking value one if workers communicate with line managers or colleagues once a month
No communication	(0/1) dummy variable taking value one if workers communicate with line managers or colleagues less often than once a month
No remote work	(0/1) dummy variable taking value one if workers never work remotely
Colprohalf	(0/1) dummy variable taking value one if the proportion of colleagues based at the same location is above 50 percent
Wrkextra9	(0/1) dummy variable taking value one if the respondent is willing to take extra responsibilities at work without being paid more of 9 and above on a 0-10 scale
Publicwrk	(0/1) dummy variable taking value one if the respondent works in the public sector
Age	Respondent's age
Hhmmb	Number of household members
Hinctnta	Domestic decile of household total net income from all sources
Stflife9	(0/1) dummy variable taking value one if the respondent has a level of satisfaction about life of 9 and above on a 0-10 scale

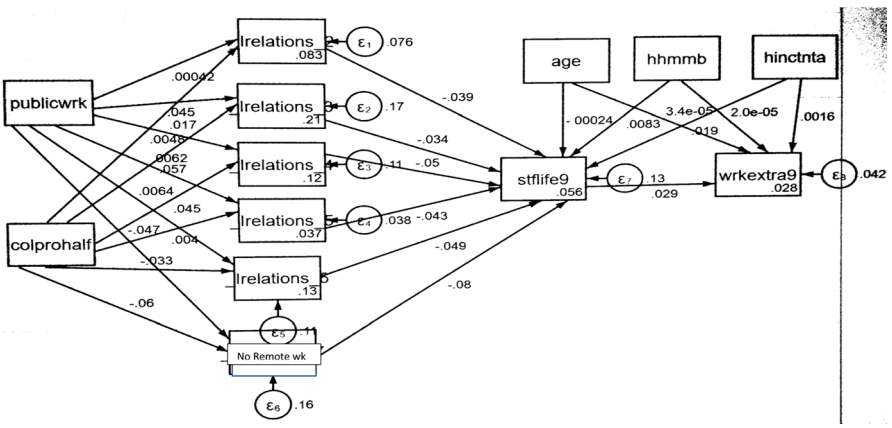

Fig. 3 SEM pathway diagram. Legend: lrelation 2: high communication; lrelation 3: medium-high communication; lrelation 4: medium communication; lrelation 5: medium-low communication; lrelation 6: low communication

but also quality, in order to increase the probability of keeping their position in an improved and more agreeable working environment.

Table 6 Descriptive statistics

	Obs	Mean	St.dev.	Min	Max
High Communication	9,091	0.083	0.276	0	1
Medium-High Communication	9,091	0.225	0.417	0	1
Medium Communication	9,091	0.132	0.339	0	1
Medium-Low Communication	9,091	0.039	0.194	0	1
Low Communication	9,091	0.139	0.339	0	1
No Remote Work	9,091	0.403	0.403	0	1
Colprohalf	9,091	0.108	0.310	0	1
Wrkextra9	9,091	0.043	0.203	0	1
Publicwrk	9,091	0.308	0.461	0	1
Age	9,037	43.605	12.598	14	89
Hhmmb	9,065	2.695	1.298	1	11
Hinctnta	7,542	6.583	2.429	1	10
Stflife9	9,091	0.147	0.354	0	1

Table 7 SEM model estimates

	Coeff EXP(OR)	*T*-stat	*p*-value
No remote work			
Colprohalf	0.942	− 4.87	0.000***
Publicwrk	0.954	− 5.35	0.000***
Const.	1.252	41.28	0.000***
Lstflife9			
High communication	0.962	− 2.20	0.029
Medium-high communication	0.966	− 2.46	0.028
Medium communication	0.951	− 3.25	0.002***
Medium-low communication	0.950	− 1.84	0.074
Low communication	0.952	− 3.16	0.002***
No remote work	0.923	− 5.85	0.000***
Age	0.999	− 0.73	0.543
Hmmbb	1.008	2.40	0.015
Hinctnt	1.019	10.70	0.000***
Const	1.058	2.57	0.016
Extrawrk9			
Lstflife9	1.029	3.49	0.000***
Age	1.000	0.18	0.861
Hmmbb	1.000	0.01	0.992
Hinctnt	1.001	1.49	0.137
Const.	1.028	2.39	0.017
Godness of Fit: Akaike information criteria			
N.obs	ll.model	df	AIC -BIC
9,091	− 16529.65	38	AIC 331353 BIC 33405.57

6.1 Dataset

To test our theoretical findings, we use data from the preliminary release of the 10th round of the ESS, which gathers information on various variables, including the intensity of time spent working from remote locations, whether workers engage with their managers and colleagues online, the type of remote work facilities utilized by workers (e.g., phone calls, messaging services), and the intensity of time spent on F2F meetings with managers and colleagues during the year 2020. These categorical variables serve as robust proxies for the key variables described in sect. 2 pertaining to the three types of interactions in the workplace.

The preliminary release of the 10th round of ESS includes 10 European countries (Bulgaria, Croatia, Estonia, Finland, France, Hungary, Czech Republic, Lithuania, Slovenia, and Slovakia). Some of these countries already implemented remote work policies before the pandemic, and other countries like the Balkans with a low or absent adoption of remote work. Based on the literature described in the introduction we proxy workers' productivity by examining their availability for extra hours of unpaid overwork, represented as an ordinal variable ranging from 1 to 9. Given our interest in very high levels of productivity, our focus is specifically on level 9.

6.2 Econometric analysis

We take the assumption that, if the share of colleagues in presence exceeds 50 percent (*colprop*), it negatively impacts high levels of life satisfaction (*Stflife9*), which in turn influences workers' productivity (*wrkextra*). Essentially, our assumption posits that working in crowded offices reduces privacy and intimacy and therefore subjective well-being. Additionally, we introduce other exogenous variables that could reasonably affect both life satisfaction and the number of extra-hours worked: individual's age (age), family income (*hhmmb*), and the number of people at home (*hinctnta*). Finally, we posit that the type of work (*typwrk*) has a direct effect on remote work (*relationsmart*). Detailed variable information is available in Table 4, while descriptive statistics can be found in Table 5.

We employ a SEM (Duncan 1975; Kaplan, 2009; Tarka 2017) approach to test our explanatory model regarding how remote work impacts workers' productivity, considering the mediating role of working at home on life satisfaction. The pathway of our empirical model is illustrated in Fig. 3, with the estimated coefficients displayed along the arrows.

More specifically, we employ a generalized SEM using a multinomial logit estimate with clustered errors in the variance. Our results validate the direction and signs of our hypotheses. In general, in workplaces where the number of colleagues is typically high, there is an increased amount of time spent working remotely. The comfort and well-being derived from managing working time at home, particularly with family, contribute to an increased propensity for unpaid extra work. This effect is particularly notable in the context of the public sector. Therefore, there exists both a direct effect of remote work on this measure of productivity and an indirect one mediated by the impact on life satisfaction (Table 6).

According to our findings, both *colprohalf* ($b = -0.059, p < 0.001$) and *publicwrk* ($b = -0.047, p < 0.001$) have an impact on *relationsmart7* when compared to a situation where the individual never works remotely (Table 7). This suggests that as the workplace becomes more crowded, the likelihood of employees never working remotely decreases, particularly in central government, other public sectors, or state-owned firms. Conversely, not working remotely has a negative and significant effect on life satisfaction ($b = -0.079, p < 0.001$). Additionally, *hinctnta* ($b = 0.019, p < 0.001$) positively and significantly influences life satisfaction, while *age* and *income* do not have significant effects. Lastly, satisfaction with life increases people's willingness to assume additional responsibility for unpaid work ($b = 0.028, p < 0.001$). This implies that working remotely significantly contributes to enhancing productivity by fostering greater life satisfaction.

Table 6 provides comprehensive regression results for the variables incorporated in the final model, illustrating their intricate interconnections within a complex network of relationships. The effects elucidated in our theoretical model find support in the Akaike Information Criteria (AIC = 33,135.3, BIC = 33,405.57, df=38), which are statistical measures aiding in model selection. The AIC reflects the balance between the model's goodness of fit and its complexity, with lower values indicating a more favorable trade-off.

7 Discussion

We are aware that our model may not be applicable to all types of businesses. For instance, sectors like the construction industry or artisanal work have limited scope for remote and flexible working activities. In such cases, the number of RS and RA interactions might need to be capped at very basic levels, if considered at all. However, our model could be particularly beneficial for sectors where hybrid working conditions are viable. This includes industries such as ICT, legal, financial, research and development, and education, among others.

We acknowledge that our assumption of output being produced using Cobb-Douglas technology might not be universally applicable. In certain contexts, the assumption of complementarity of interactions is reasonable, given the distinct features of face-to-face (F2F) interactions contributing to brand identity and relationship quality, consequently enhancing the productivity of remote relationships. However, in some instances, firms might find it more appropriate to model their production using a linear or Leontief production function. We however believe that the current organization of firms and the tasks and preferences of workers make feasible in most cases some forms of substitution among the three types of inputs, which motivates our choice.

Another critical aspect is the number of interactions within the same unit or across different, geographically distant units. However, this consideration applies to a specific type of firm. The frequency with which workers within the same unit

interact among themselves, or with employees from other units, can have implications for costs and productivity. On one hand, within-unit interactions may be more cost-effective and productive as they take place in the same location and involve individuals who are already acquainted. On the other hand, between-unit interactions may also be more cost-effective and productive if they leverage the comparative advantages and expertise of other units.

Overall, it is reasonable to believe that remote interactions are more likely to occur when the needs of frequent work meetings among differently located units are higher, as remote working conditions offer greater opportunities for collaboration among individuals located in different places and following different schedules.

The nature of working tasks and the feasibility of remote work are also contingent on job types and seniority within an organization. For instance, managers are more likely to engage in interactions with colleagues from other units or firms, potentially making remote work more applicable to their roles. Conversely, certain assembly line workers may be restricted to onsite work due to the nature of their tasks. Additionally, accounting for onboarding needs may require model adaptation since junior workers or new staff may necessitate more face-to-face interactions to learn through hands-on experience and establish a robust relational network within the company. The variability in job types and seniority levels underscores the nuanced considerations involved in implementing remote work arrangements.

Teleworking options are additionally contingent on the quality of infrastructure in remote settings. Workers performing their tasks at home or any location outside the office necessitate a suitable working environment, often requiring high-quality broadband access. The feasibility of remote work is therefore significantly influenced by neighborhood characteristics, such as noise pollution and broadband speed capacity, as well as household conditions, including care responsibilities and the number of rooms available. Moreover, one drawback of teleworking is the potential for blurring the boundary between leisure and work activities, possibly leading to the overexploitation of employees, especially junior staff. Striking the right balance and addressing these practical considerations is essential for effective teleworking arrangements.

In addition to the drawbacks mentioned so far, we also observe how costs for workers, firms, and society as a whole may change in response to a higher proportion of teleworking. Various innovations in the digital sector, such as the development of cloud storage and file synchronization services, have facilitated the remote performance of many tasks at lower monetary and time costs, resulting in increased productivity. These advantages extend beyond individual firms and workers to have societal spillovers. First, they contribute to enhancing the exchange of the public good of information, thereby mitigating the market failure associated with its socially optimal underproduction. Second, they enable workers to improve the quality of their time use, diversify risks, and reduce costs associated with interactions that may turn out to be unnecessary ex post.

Specifically regarding the impact on costs, the opportunity to transition from in-person to remote interactions can be perceived as a form of flexible work commuting

rent that can be shared between employees and employers. For example, companies like Google have implemented policies where employees opting for teleworking may experience a reduction in wages, offsetting the lower cost of living and commuting.[3] This practice is particularly relevant in large cities, where relative house prices and congestion are higher (Croce and Scicchitano, 2022). Part of this rent is also realized through a reduction in the need for office workspaces, resulting in a significant decrease in the required office space and, consequently, corporate fixed costs.

7.1 Policy suggestions to regulate teleworking

All the complexities associated with hybrid working patterns, including factors like sector, job type, seniority, and infrastructure, contribute to economic and social inequality. To tackle this issue, both governments and firms must acknowledge that teleworking can influence inequality within firms and across industries. Implementing monetary mechanisms to compensate for such wealth differentials and varied retirement conditions can be a viable approach to address these disparities and foster a more equitable work environment.

More specifically, in the context of government involvement, corporate decisions to adopt the hybrid model generate dual positive effects on environmental sustainability and worker satisfaction. While our model acknowledges that part of the work-life balance externality positively impacts the company through increased productivity, the environmental externality remains a pure externality. Consequently, the socially optimal proportion of remote relationships surpasses that achieved solely through private decision-making. This externality's significance amplifies during pandemics, wherein the reduction in contagion risk and associated outcomes constitutes an additional positive externality. The comprehensive assessment of these externalities is crucial in evaluating telework from a multidimensional well-being perspective.

Regarding corporate policies, the shift to hybrid job contracts can be transformed from being perceived as unfair, inequitable, and discriminatory to being just, worker-centered, and innovative with a few considerations. First, the onboarding process for newly hired workers should preferably take place in the office more frequently during the probation period, potentially alongside their mentors. This would enable them to build relationships with colleagues, become familiar with tasks and work peculiarities, and gain an understanding of the needs and challenges associated with different types of work interactions. Second, companies should refrain from expecting any worker to be active outside the standard working time schedule (i.e., Monday through Friday, 9 am to 5 pm). This aligns with the concept of the right to disconnect, which has been

[3] https://www.bbc.co.uk/news/business-58171716. Table 9 in the appendix provides a list of the largest companies that adopted full remote work policies.

discussed in several countries worldwide[4] but still lacks clear, homogeneous regulation. Third, firms must consider economic disadvantages for those who can hardly or cannot work remotely, and wages should be adjusted accordingly.

Monetary and non-monetary benefits for workers living in deprived areas, residing in houses with uncomfortable working conditions, having caring responsibilities, or facing challenges in working remotely due to their job tasks can be compensated using the cost savings enjoyed by firms. Fourth, workers exhibit heterogeneous preferences for remote interactions, with some being extremely enthusiastic and others more skeptical. This implies, contrary to our model assumptions, that some workers may become more productive, while others may experience a slowdown in their production. Firms should view telework as an opportunity for the former group of workers, aiming for optimal resource allocation that aligns with the objectives of both the firms and the workers.

Companies may consider offering a variety of contracts that allow teleworking activities to be concentrated in a specific period of the year or spread out over a few hours each day. Similar to annual leave policies designed to protect rights of both employees and employers, a fixed amount of remote working periods can be established through agreements between workers and their line managers. This approach helps strike a balance that accommodates varying preferences and circumstances among employees.

8 Conclusions and direction of further research

As the digital revolution continues to expand, there is an imperative need for a more profound understanding of how to manage teleworking options and their impact on the well-being of workers and firms' outputs. This paper addresses this need by modeling firms' decisions on the allocation of work among onsite, remote simultaneous, and remote sequential interactions. Specifically, we delineate and discuss the potential costs and benefits for both firms and workers when transitioning from in-person to remote interactions. These considerations encompass five key features: cost savings, frequency of interactions, optimal time/space allocation, work-life balance, and relational quality.

In our model we start from the assumption that in contemporary corporate life spent performing complex tasks, productivity mainly passes through workers interactions. We therefore use an innovative production function where the three types of relationship are inputs, solve the optimization problem for hybrid companies and determine the optimal share of each type of interaction. We calibrate our model using various input values, demonstrating that companies optimally shift from in-person to asynchronous and remote interactions as long as productivity gains (in

[4] See, for instance, the European Parliament resolution of 21 January 2021, accessible at https://www.europarl.europa.eu/doceo/document/TA-9-2021-0021_EN.html.

terms of work-life balance, optimal time/place slots, and higher frequency of interaction) outweigh relationship decay.

Remote asynchronous relationships tend to dominate remote synchronous relationships unless an additional value of synchronicity is assumed. We then compare the performance of a company strategically choosing among the three relationship types with a company constrained to onsite relationships, highlighting the substantial efficiency gains of hybrid models.

Empirically, we find support for the main hypothesis of our theoretical analysis trough a generalized SEM showing that remote work enhances the life satisfaction and productivity of workers.

Our work carries several implications for corporate and government policies. Firstly, our model can serve as an initial benchmark theoretical framework that policymakers and managers can adopt to optimally determine their hybrid work conditions based on measurable parameters. Secondly, companies are advised to allocate in-person activities more toward team building and fostering worker relationships rather than practical tasks. This approach would maximize the impact of both onsite and online activities by enhancing productivity and mitigating relationship decay. Thirdly, investments in universal access to high-quality broadband could significantly enhance corporate productivity, increasing gains by allowing workers to choose a higher share of second and third-type relationships and, consequently, optimizing their time/space working slots. It is crucial to recognize that achieving universal access requires effective public intervention and regulation, as profit-maximizing companies may prioritize investments in high-income areas over internal and rural regions

Appendix

See Tables 8 and 9.

Table 8 Companies adopting a hybrid model for remote work (Year 2022)

Company	Sector	Description of the policy	Source
Adobe	Software	50% of the employees are allowed to work from home	https://www.techrepublic.com/article/adobe-announces-permanent-shift-to-hybrid-work-for-its-employees/
Amazon	Online retailer	Hybrid model with employees using teleworking options for 2 days a week	https://www.cnbc.com/2021/06/10/amazon-will-let-employees-work-remotely-two-days-a-week.html#:~:text=Amazon%20on%20Thursday%20relaxed%20its,office%20three%20days%20per%20week
Benetton	Textile	Part-time remote working options both horizontal, vertical, and mixed, can be extended up to 20% of people. Flexible working options are made structural. Options to choose their preferred scheme for workers except of senior executives. Introduction of "Short Friday" with working time reduced by one hour	https://www.ilsole24ore.com/art/nella-nuova-normalita-benetton-smart-working-piu-part-time-e-venerdi-breve-AEu8ijh
Capital One	Financial services	Flexible hybrid model without requiring employees to work at the office for a given number of days per week. Some employees are allowed to work from home entirely	https://www.capitalone.com/about/newsroom/hybrid-work/
Coinbase	Crypto currencies services	Most staff who want to work remotely to do so indefinitely	https://www.linkedin.com/pulse/18-major-companies-have-announced-employees-can-work-from-scott
Electrolux		All Italian sites work on a 60% seat capacity	https://iusletter.com/oggi-sulla-stampa/smart-working-ondata-in-calo-800mila-rientrati-in-azienda/
Enel	Energia	All employees located in Rome will continue to work remotely. Call centre employees work at the office one week a month. While other job roles work in person 2 consecutive days a week	https://roma.repubblica.it/cronaca/2021/08/28/news/smart_working_grandi_societa_riaprono_remoto_coronavirus_vaccini_aziende-315563806/

Table 8 (continued)

Company	Sector	Description of the policy	Source
ENI	Energia/Gas	During the emergency peak of the pandemic, almost all workers used remote work options, including part of the staff of the operating sites. When restrictions have been eased, the share of remote workers was reduced to 50 percent	https://www.corriere.it/economia/lavoro/cards/smart-working-cosa-succedera-italia-ottobre-proroga-dell-eni-cosa-fanno-altri/eni-orientata-mantenere-smart-working.shtml
Ericsson	Information and communication technology	Teleworking for 100% of the company population until October 2023, with the plan to allow every worker to work from home for up to 12 days a month	https://www.corriere.it/economia/lavoro/cards/smart-working-cosa-succedera-italia-ottobre-proroga-dell-eni-cosa-fanno-altri/eni-orientata-mantenere-smart-working.shtml
Ferrero	Food	One day a week of remote work for all workers	https://torino.repubblica.it/cronaca/2021/11/08/news/da_intesa_a_ferrero_sullo_smart_working_aziende_in_ordine_sparso-325505677/
Ferrari	Automobile	Massive use of flexible work. Ferrari, traditionally against teleworking, in two weeks was converted in order to allow 80% of indirect employees to work using hybrid options	https://www.wired.it/economia/lavoro/2020/04/30/ferrari-fase-2-coronavirus/
Ford Motor	Automobile	Employees are allowed to work from home indefinitely with flexible hours. Hybrid work have been introduced for group meetings and projects where needed	https://www.forbes.com/sites/jackkelly/2021/03/21/iconic-american-automaker-ford-motors-says-employees-can-work-from-home-indefinitely-with-their-new-redesigned-hybrid----------in-office-and-remote-model/
Google	Information and communication technology	In December 2020 the company announced a plan allowing its workers to work remotely for three days a week In 2021, the company expected 60% of its employees work on site for a few days a week, 20% working in new office locations, and 20% entirely working from home	https://www.cnbc.com/2021/05/05/google-relaxes-remote-work-plan-will-let-20percent-of-employees-telecommute.html

Table 8 (continued)

Company	Sector	Description of the policy	Source
Intesa SanPaolo	Banking and financial sector	The company continues as per its 2016 agreement and provides up to 8 days a month of remote work	https://www.today.it/economia/smart-working-grandi-aziende.html
Leonardo	Tech	Flexible working options are an integrated part of the organization. The company guarantees voluntariness, right to disconnect, periods of availability, and flexibility management for the workers, upon agreements with line managers	https://www.ilsole24ore.com/art/lavoro-agile-40percento-imprese-continua-usarlo-anche-post-emergenza-AEeUqbHB
HubSpot	Marketing and sales platform	Employees can choose from three options: work from home with an approved home office setup, work from the office one or two days per week, or work from the office three or more days per week. New employees will have to choose their option prior to their start date and can change once a year	https://www.flexjobs.com/blog/post/companies-switching-remote-work-long-term/
Lavazza	Food	The company offers the possibility to work remotely 1 day per week options since 2018. During the pandemic, this was increased up to 5 days per week. The intention is to maintain a hybrid scheme with 2 days per week	https://torino.repubblica.it/cronaca/2021/11/08/news/da_intesa_a_ferrero_sullo_smart_working_aziende_in_ordine_sparso-325505677/
LogMein	Software	Some workers work remotely 100% of their time, while others have a hybrid arrangement. Depending on their role, a small percentage of employees work at the office four to five days per week	https://www.logmein.com/it/newsroom/press-release/2021/logmein-creates-new-digital-workplace-team-to-support-employee-and-customer-shift-to-hybrid-working

Table 8 (continued)

Company	Sector	Description of the policy	Source
Microsoft	Technology	Employees can work from home for approximately 50% of their workweek. This can be extended to 100% upon line managers approval	https://blogs.microsoft.com/blog/2021/03/22/the-philosophy-and-practice-of-our-hybrid-workplace/
Nationwide Insurance,	Financial Services	The company is making a permanent transition to a hybrid work model, with a majority of the staff being able to work entirely from home	https://www.nytimes.com/2021/08/05/business/dealbook/remote-work-bias.html
Pirelli	Automobile	60% of the employees working remotely	https://iusletter.com/oggi-sulla-stampa/smart-working-ondata-in-calo-800mila-rientrati-in-azienda/
Poste Italiane	Postal and financial services	From October 2021 all workers previously working from home are invited to return at the offices, except for vulnerable people	https://www.today.it/economia/smart-working-grandi-aziende.html
Quora	Online Platform	The company has adopted a remote-first policy, allowing nearly all employees to work remotely and relocate to anywhere the company can legally employ them. The company will convert its existing office into a coworking space for employees who want to work there	https://www.flexjobs.com/blog/post/companies-switching-remote-work-long-term/
Reddit	Online Platform	The company allows employees to choose permanent remote work, with options for in-office work in a casual environment	https://www.flexjobs.com/blog/post/companies-switching-remote-work-long-term/
SalesForce	businesses of all shapes and sizes	Hybrid model. The company offers three categories of flexible work for its employees: flex (at the office one to three days per week), fully remote, and office-based (the small number of staff who need to be available in person four to five days per week)	https://www.flexjobs.com/employer-blog/salesforce-flexible-work-plans/

Table 8 (continued)

Company	Sector	Description of the policy	Source
Siemens	Conglomerate	140,000 of employees can permanently work from home for two to three days per week	https://www.flexjobs.com/employer-blog/siemens-mobile-work-employees/#:~:text=Under%20the%20permanent%20plan%2C%20and,to%20three%20days%20a%20week.
Snam	Gas	The company has chosen to gradually bring workers back to all locations at least 2 days a week. As part of its health and safety protocol, the company has limited the maximum number of workers at the offices to 50%	https://iusletter.com/oggi-sulla-stampa/smart-working-ondata-in-calo-800mila-rientrati-in-azienda/
Spotify	Real time communication	Hybrid model. Employees can choose to work at the office, remotely, or in a company-paid coworking space	https://www.forbes.com/sites/kristinstoller/2021/01/31/never-want-to-go-back-to-the-office-heres-where-you-should-work/?sh=4ff488156712
Stellantis	Automobile	As of May 2021, about 90% of the Lingotto employees (i.e., approximately 6,500 employers) in Italy work remotely most of their time In the United States, Stellantis has launched a pilot project allowing 70% of the workforce to work from home. In Germany, Opel aims to reduce available workstations by 90% in order to drastically cut the number of offices and therefore real estate costs	https://www.ripartelitalia.it/stellantis-punta-sul-telelavoro-raggiunto-un-accordo-con-i-sindacati-francesi-per-dare-a-18-mila-dipendenti-la-possibilita-di-lavorare-da-remoto/#:~:text=Per%20mantenere%20queste%20percentuali%20oltre,casa%2C%2030%25%20in%20ufficio.
Tim	Telecommunic.	At the end of the state of emergency, based on the union agreement set in 2020, all workers are expected to return to the office using teleworking options, i.e., for 3 days a week or 2 weeks a month	https://iusletter.com/oggi-sulla-stampa/smart-working-ondata-in-calo-800mila-rientrati-in-azienda/

Table 8 (continued)

Company	Sector	Description of the policy	Source
Unicredit	Banking and financial Services	The company starts a pilot project offering employees the opportunity to work from home 40% of their working time	https://www.corriere.it/economia/lavoro/21_luglio_01/unicredit-smart-working-2-giorni-settimana-tutti-dipendenti-932b5d68-da77-11eb-b90a-fb70429ba8fb.shtml#:~:text=Unicredit%20si%20prepara%20a%20un,lavoro%20post%2Dpandemia%20saranno%20conclusi
Unipol	Insurance	The company offers flexible work options for counter staff, subject to guaranteeing customer service	https://iusletter.com/oggi-sulla-stampa/smart-working-ondata-in-calo-800mila-rientrati-in-azienda/
Verizon	Global communications	Hybrid model. The company is offering a range of remote options depending on job role	https://buildremote.co/companies/companies-going-remote-permanently/
Zoom	Video communications	Hybrid model: the company strategically mix remote and in-office work	https://blog.zoom.us/how-zoom-is-approaching-our-next-phase-of-work/
Windtre	Telecomm.	High flexibility in alternating between work-places or other places and applies to all employees whose activities can be carried out remotely, including customer care staff. The smart working days may be requested by workers voluntarily, without constraints in terms of minimum or maximum size, and any days on which to go to the office will be identified with their manager, in order to stimulate social and relational interaction as a factor. of professional growth. The new work organization will be operational from 1 April 2021 until 31 March 2022	https://www.windtregroup.it/IT/Press-&-Events/comunicati-stampa/Comunicati-Istituzionali/2021/WINDTRE_ACCORDO_SMART_WORKING.aspx?Source=https://www.windtregroup.it/IT/Press-&-Events/comunicati-stampa.aspx

Table 9 Company opting for 100% teleworking (Year 2022).

Company	Sector	Description of the policy	Source
Apple	IT	100%. Optional for some job roles during the pandemic; hybrid options when restrictions are eased	https://www.computerworld.com/article/3652613/apple-joins-the-great-return-to-hybrid-work.html
Atlassian	Computer software business	100%	https://www.linkedin.com/news/story/atlassians-workers-can-wfh-forever-4191073/#:~:text=The%20tech%20company%20Atlassian%20has,least%20the%20middle%20of%202021.
Facebook	Social media network	100%. All the employees can work from home permanently	https://www.virtualvocations.com/blog/remote-job-leads/25-companies-going-remote-permanently/
Ford Motor	Automobile	100%. Employees will be allowed to work from home indefinitely with flexible hours. Hybrid work will be introduced for group meetings and projects where needed	https://www.forbes.com/sites/jackkelly/2021/03/21/iconic-american-automaker-ford-motors-says-employees-can-work-from-home-indefinitely-with-their-new-redesigned-hybrid----------in-office-and-remote-model/
Generali	Insurance	100% until the end of pandemic	
Lambda School	School online	100%. The company has rolled out a permanent work-from-anywhere policy, and employees can work from anywhere in the United States	https://traqq.com/blog/here-are-18-companies-that-have-switched-to-long-term-remote-work/#:~:text=Lambda%20School&text=The%20platform%20works%20uniquely%20in,long%20as%20it%20suits%20them
Lincoln Financial Group	Financial Services	100%. All employees are eligible for permanent remote work	https://www.virtualvocations.com/blog/remote-job-leads/25-companies-going-remote-permanently/
Shopify	E-commerce company	100%. All employees can work from home indefinitely	https://www.forbes.com/sites/kristinstoller/2021/01/31/never-want-to-go-back-to-the-office-heres-where-you-should-work/?sh=4ff488156712
SAP	Software	100%. The company adopts a flexible, trust-based work model	https://news.sap.com/2021/06/pledge-to-flex-future-of-work-at-sap/
Slack	Online learning	100%. Most of the employees can work from home permanently, and the company aims at hiring remote employees more permanently	https://www.forbes.com/sites/kristinstoller/2021/01/31/never-want-to-go-back-to-the-office-heres-where-you-should-work/?sh=4ff488156712

Table 9 (continued)

Company	Sector	Description of the policy	Source
Square	Financial services online	100%. Employees will be able to work from home permanently	https://www.forbes.com/sites/kristinstoller/2021/01/31/never-want-to-go-back-to-the-office-heres-where-you-should-work/?sh=4ff488156712
Twitter	Social network	100%. Employees will be able to work from home indefinitely, going to the office on a voluntary basis	https://www.forbes.com/sites/jackkelly/2022/03/05/twitter-employees-can-work-from-home-forever-or-wherever-you-feel-most-productive-and-creative/
VMware	IT	100%. The company offers permanent remote working to all the employees	https://www.flexjobs.com/remote-jobs/company/vmware

Declarations

Conflict of interest All authors declare that they have no conflict of interest.

References

Abilash M, Siju NM (2021) Telecommuting: an empirical study on job performance, job satisfaction and employees commitment during pandemic circumstances. Shanlax Int J Manag 8(3):1–10

Akerlof GA (1982) Labor contracts as partial gift exchange. Q J Econ 97(4):543–569

Akerlof GA (1984) Gift exchange and efficiency-wage theory: four views. Am Econ Rev 74(2):79–83

Anakpo G, Nqwayibana Z, Mishi S (2023) The impact of work-from-home on employee performance and productivity: a systematic review. Sustainability 15:4529

Arkesteijn MH, Jansen SJT, Kieft B, Appel-Meulenbroek R, Hoekstra B, Jongens-Van der Schaaf P (2021) The influence of the physical home work environment on perceived productivity during the COVID-19 pandemic. In: The proceedings of the 20th EuroFM research symposium 2021, European Facility Management Network (pp 7-12). EuroFM

Barrero JM, Bloom N, Davis Steven J (2021) Why working from home will stick. NBER Working Papers 28731. National Bureau of Economic Research

Becchetti L, Florio E, Mancini S (2021) Internet exposure and social capital. Available at SSRN: http://dx.doi.org/10.2139/ssrn.3923612

Bicchieri C, Lev-On A (2007) Computer-mediated communication and cooperation in social dilemmas: an experimental analysis. Politics, Philos Econ 6(2):139–168

Bloom N, Liang J, Roberts J, Ying ZJ (2015) Does working from home work? Evidence from a Chinese experiment. Quart J Econ 130(1):165–218

Boys J (2020) Working from home: what's driving the rise in remote working. Chartered Institute of Personnel and Development, London

Calcagnini G, Giombini G, Travaglini G (2021) The productivity gap among major European countries USA and Japan. Ital Econ J 7(1):59–78

CIPD—Chartered Institute of Personnel and Development (2020). Home working is set to more than double compared to pre-pandemic levels once the crisis is over. CIPD Press Release, available at https://www.cipd.co.uk/about/media/press/homeworking-increases

Clark SC (2000) Work/family border theory: a new theory of work/family balance. Hum Relat 53(6):747–770

Croce G, Scicchitano S (2022) Cities and working from home in Italy in the post Covid-19 age. Rivis Ital Polit Pubbl 17(2):191–217

Davidescu AA, Apostu SA, Paul A, Casuneanu I (2020) Work flexibility, job satisfaction, and job performance among Romanian employees-implications for sustainable human resource management. Sustainability 12:608

De Menezes LM, Kelliher C (2011) Flexible working and performance: a systematic review of the evidence for a business case. Int J Manag Rev 13(4):452–474

Duncan OD (1975) Introduction to structural equation models. Academic Press, New York

Elsbach KD, Cable DM, Sherman JW (2012) How passive "face time'' affects perceptions of employees: evidence of spontaneous trait inference. Hum Relat 65(6):759–780

Felstead A, Henseke G (2017) Assessing the growth of remote working and its consequences for effort, well-being and work-life balance. N Technol Work Employ 32(3):195–212

Freeman RB (1997) Working for nothing: the supply of volunteer labor. J Lab Econ 15(12):S140–S166

Gallardo R, Whitacre B (2018) 21st century economic development: telework and its impact on local income. Reg Sci Policy Pract 10(2):103–123

Geraci A, Nardotto M, Reggiani T, Sabatini F (2022) Broadband internet and social capital. J Public Econ 206:104578

Gibbs M, Mengel F, Siemroth C (2021) Work from home & productivity: evidence from personnel & analytics data on IT professionals. Becker Friedman Institute, University of Chicago Working Paper 2021–56

GitLab (2020) The remote work report by GitLab: the future of work is remote. Available at https://about.gitlab.com/resources/downloads/remote-work-report-2021.pdf [Accessed on 27 Apr 2022]
Giovanis E (2018) The relationship between teleworking, traffic and air pollution. Atmos Pollut Res 9(1):1–14
Golden TD (2006) The role of relationships in understanding telecommuter satisfaction. J Organ Behav 27:319–340
Harker Martin B, MacDonnell R (2012) Is telework effective for organizations? A meta-analysis of empirical research on perceptions of telework and organizational outcomes. Manag Res Rev 35(7):602–616
Hashim R, Bakar A, Noh I, Mahyudin HA (2020) Employees' job satisfaction and performance through working from home during the pandemic lockdown. Environ Behav Proc J 5(15):461–467
Hoornweg N, Peters P, Van der Heijden B (2016) Finding the optimal mix between telework and office hours to enhance employee productivity: A study into the relationship between telework intensity and individual productivity, with mediation of intrinsic motivation and moderation of office hours. Emerald Group Publishing Limited, In New Ways of Working Practices
ILO-International Labour Organization (2021) Teleworking arrangements during the COVID-19 crisis and beyond. Available at https://www.ilo.org/wcmsp5/groups/public/---dgreports/---ddg_p/documents/publication/wcms_791858.pdf. [Accessed on 21 Mar 2022]
Kaplan D (2009) Structural equation modeling: foundations and extensions, 2nd edn. Sage, Los Angeles
Kelliher C, Anderson D (2010) Doing more with less? Flexible working practices and the intensification of work. Hum Relat 63(1):83–106
Kniffin KM, Narayanan J, Anseel F, Antonakis J, Ashford SP, Bakker AB, Vugt MV (2021) COVID-19 and the workplace: implications, issues, and insights for future research and action. Am Psychol 76(1):63
Kosteas VD, Renna F, Scicchitano S (2022) Covid-19 and working from home. Handbook of Labor, Human Resources and Population Economics, pp 1–26
Milasi S, González-Vázquez I, Fernández-Macías E (2020) Telework in the EU before and after the COVID-19: where we were, where we head to. The European Commission's science and knowledge service Policy Brief, joint research centre, European commission. Available at https://ec.europa.eu/jrc/sites/default/files/jrc120945_policy_brief_-_covid_and_telework_final.pdf [Accessed on 21 Mar 2022]
Mirchandani K (2000) "The best of both worlds'' and "cutting my own throat'': contradictory images of home-based work. Qual Sociol 23(2):159–182
Nakrosiene A, Buciuniene I, Gostautaite B (2019) Working from home: characteristics and outcomes of telework. Int J Manpow 40(1):87–101
Ravi N, Anulakshmi MR (2021) Work from home and employee productivity during COVID-19. Asian Basic Appl Res J 3(4):14–21
Rubin O, Nikolaeva A, Nello-Deakin S, te Brömmelstroet M (2020) What can we learn from the COVID-19 pandemic about how people experience working from home and commuting? Centre for Urban Studies, University of Amsterdam
Saba T, Cachat-Rosset G, Marsan J, Klarsfeld A, Carillo K (2020) COVID-19 crisis triggers teleworking: a global cure or a short-term solution. Université de Montréal, Montréal
Sardeshmukh SR, Sharma D, Golden TD (2012) Impact of telework on exhaustion and job engagement: a job demands and job resources model. N Technol Work Employ 27(3):193–207
Shobe K (2018) Productivity driven by job satisfaction, physical work environment, management support and job autonomy. Bus Econ J 9:1–9
Subing FH, Waskito B (2023) Effects of work-life balance, physical work environment, and non-physical work environment on employee job satisfaction at PT Bank Lampung. J Manag Bus Soc Sci 1(3)
Tarka P (2017) An overview of structural equation modeling: its beginnings, historical development, usefulness and controversies in the social sciences. Qual Quant 52(1):313–54
Xiao E, Houser D (2005) Emotion expression in human punishment behavior. Proc Natl Acad Sci 102(20):7398–7401
Wheatley D (2012) Employee satisfaction and use of flexible working arrangements. Work Employ Soc 31(4):567–585