Chapter 7
Environmental implications of agile working: an assessment of commuting emissions

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ABSTRACT
Agile working is an organizational innovation that has a significant impact on the business, on the society, and on the environment, too. The latter is the focus of our work, which aims to identify the effects of smart working on CO2 emissions generated by less commuting.
Our study refers to a survey conducted on 2,921 workers at CNR during the pandemic.
According to Istat census, the majority of the Italian workers travels prevalently by car, and our survey confirms it for the R&D worker sample, too. Usually, our sample produces 10,200 kg of CO_2 per each working day made by travelling by car (8,000 kg) and by public transports (2,200 kg). Because of the high CO2 impact of the commuting, we estimated an emissions' saving of 5,000 kg CO2 thanks to the introduction of agile working during the pandemic. The legacy of the pandemic experience is a change in the habits of commuting, partly shifting towards clean transports (additional saving of 89 kg per day).
The results of the paper should be taken into consideration by policy makers as the energy policy and the environmental policy in Italy have to be implemented by different programmes, even supporting new habits for consumers, producers, and workers.

KEYWORDS: environmental sustainability, commuting emissions.

ISBN (online): 978-88-98193-26-4
ISBN (print): 978-88-98193-27-1

HOW TO CITE THIS CHAPTER
Falavigna, G., Rota, F.S., Sella, L., & Vitali, G. (2022). Environmental implications of agile working: an assessment of commuting emissions. In Reale, E. (ed). *Agile working in Public Research Organizations during the COVID-19 pandemic. Organizational factors and individual attitudes in knowledge production* (pp. 101-115). Quaderni IRCrES 14. Moncalieri, TO: CNR-IRCrES. http://dx.doi.org/10.23760/2499-6661.2022.14

1. INTRODUCTION

The widespread adoption of agile working is generally considered an organizational innovation with significant benefits. In recent years, this relatively straightforward and deterministic argument has gained more and more attention, up to the paramount explosion of interest in agile working registered during the first wave of the COVID-19 pandemic. The new challenges that have emerged due to the pandemic led, in fact, to the most extensive mass experiment of agile working in history and allowed testing the implications of this organizational model from many different perspectives (Loia & Adinolfi, 2021).

During the first wave of the pandemic, data from the International Labour Organization, the International Energy Agency, the World Bank and other international organizations converged in indicating that about 20% of the world labour force moved to agile working, with a strong positive correlation with GDP per capita, at the national level, and with worker's salary, at the microeconomic level (OECD, 2020).

Today, two years have passed since the pandemic outbreak, and the availability of vaccines has softened the health emergence and the need for social distancing measures. Thus, in many countries, we observe a diffused return of activities in presence. In such a context, a big argument debated by governments and organizations is the opportunity of introducing agile working in regular job practices and its economic, social and environmental implications.

The spread of agile working can emerge as a solution to safeguard jobs and economic activities, but also as the opportunity to improve the efficacy and quality of the working activity. Agile working can increase firm-level productivity, even if the adverse effects of remoteness on communication, knowledge flows and managerial oversight lead to an inverted U-shaped relationship between agile working and productivity (OECD, 2020). Agile working can also improve workers' satisfaction and organizations' efficiency. However, organizations need to balance agile working properly. The mix of remote and in-presence activities that maximise the effects on workers and productivity is different for the different types of organization and production cycle. The digital attitudes of the workers also emerge as critical prerequisites to ensure that the experiments conducted during the pandemics will develop towards an effective and efficient agile business model (Lake, 2013).

Consistent with this, we observe that investments in digitalisation are one of the pillars of the European Union' plan to exit the COVID-19 crisis. In the perspective of this plan (also known as Next Generation EU), the new reliance on agile working and digital platforms accelerated by the pandemic paves the way for a holistic strategy of digital innovation (Kattami, 2020) that will limit anthropic pressures while supporting economic and social recovery. On the one hand, the EU strategy assumes that environment-friendly lifestyles produce healthier communities, where infectious pathogens are less diffused and dangerous. On the other hand, it recognises the feasibility and opportunity of a more extensive recourse to agile working and digital solutions to make the economy of the European Union more competitive and sustainable. In general, the literature suggests that, at the global level, in 2020 the COVID-19 pandemic led to a drastic reduction of work commuting that reduced both gas emissions (i.e., GHG emissions) and air pollutants (Forster et al., 2020).

The main objective of this study is to establish to what extent the 2020 experience of agile working in Italian Public Research Organizations could affect mobility GHG emissions.

In a perspective of agile working as an eco-innovation, public organizations are likely to be as important as private ones concerning workers' daily mobility and emissions.

Thanks to the high number of the involved employees, the adoption by the public sector of structural forms of agile working is expected to generate a relevant modification of individual and collective mobility behaviours and a positive impact on the environment, comparable with the private counterpart. Public Research Organizations (PROs), in particular, emerge among other types of public organizations for a significant presence of highly-skilled and qualified workers and the adoption of innovative organizational models prone to the public interest and the

environment. In our analysis, PROs thus emerge as ideal candidates for experimenting with agile working practices to promote sustainable development.

The main research questions of the paper are:

- to what extent can agile working in PROs have a positive environmental impact on work mobility emissions?
- how can the new labour organization maximize this positive impact?

Moreover, we consider the possibility that agile working experience will modify in the long-term run the environmental attitude of workers towards more eco-friendly transportation habits.

To shed light on these questions, this study exploits the opportunity given by the questionnaire distributed to researchers and technologists (R&Ts) at CNR, the National Research Council of Italy, and INAF, the National Institute for Astrophysics, during the first wave of the COVID-19 pandemic (in year 2020).

The structure of this paper is as follows. Section 2 provides an overview of the literature about the relationships between agile working and transport emissions, whereas section 3 reviews the methodology applied in Italy to assess the impact of agile working on the environment. Section 4 presents the results of the sections of the questionnaire that capture the environmental behaviour of about 3.000 researches of CNR and INAF, i.e. two PROs under the supervision of the Italian Ministry of University and Research (see Fabrizio et al., 2021 for details). Finally, section 5 draws some considerations about the use of agile working as an organizational innovation supporting the sustainable development of our society.

2. AGILE WORKING AND ENVIRONMENT: EMERGING ISSUES

Most of the arguments used by the scientific and policy debate to support the adoption of agile working were already present in the 1970s and 80s, when remote working started being experimented as a solution to the oil crisis and employees' potential inability to get to work (Torten et al., 2016). Then, subsequent advancements in the information and communication technologies (ICTs) contributed to turn agile working into a viable and competitive alternative to traditional working. Particularly, agile working proved to be effective in leading to cost advantages – to both employees and employers – and improvements in productivity, working motivations and environmental impacts (Turetken et al., 2011). Despite its slow adoption over time – delayed by organizational and cultural prejudices that labelled it as an occasional work pattern (Loia & Adinolfi, 2021) –, the interest in agile working kept on growing (Tortenet al., 2016). Since the beginning of the new millennium, it started to be considered a manifestation of the broader digital/network restructuring of the contemporary economy and society (Castells, 2000).

At the very beginning, the debate on agile working mainly focussed on the savings in time and costs it enabled. Soon, however, environmental sustainability considerations on the positive effects of agile working started to diffuse (Loia & Adinolfi, 2021; Belzunegui-Eraso & Erro-Garcés, 2020). In the public policy debate, namely, the adoption of agile working started to be discussed as a solution to the diseconomies of road congestion (Harpaz, 2002). Public policies for agile working were initially conceived and designed to reduce the excessive recourse to private means of transport to get to work (car commuting), causing congestion, noise, pollution, waste of time and overall inefficiency of the local transport system. Later, an increasing portion of studies has pointed out the positive ecological implications of agile working (Loia & Adinolfi, 2021).

In the last twenty years, agile working gained attention due to the fast worsening of the global environmental scenario and the new centrality assumed by the risks of pollution, climate change and the consumption of natural resources. In Europe, the interest to agile working as a practice for environmental sustainability has emerged also from an intense production of public policies

such as the "Smart cities and communities' strategy" and other initiatives pushing investments in digitalisation to fulfil sustainable growth objectives.

The economic literature considers the shift from in-presence to agile working as an organizational innovation favourable to environmental sustainability. In the private and the public sector, agile working can in fact allow a consistent net reduction in daily commuting, which constitutes an advantage for the environment. Some authors celebrate this positive dimension even further, defining agile working as an eco-innovation for sustainable development (Loia & Adinolfi, 2021).

In 2020, the extraordinary number of organizations and workers compelled to experience agile working due to the pandemic allowed an unprecedented amount of information to evaluate the effects of this working organizational model from many different perspectives and points of view (Fabrizio et al., 2021).

As a first outcome, these analyses produced a widespread recognition that a massive, intensive and prolonged recourse to agile working implies disadvantages as well as advantages (see Chapter 5). Consistent with Harpaz (2002), if we simultaneously consider the multiple dimensions of agile working, which include social, economic and environmental issues, the evaluation of the balance of pros and cons is far from an easy task. Also when we focus on a single aspect (i.e. the implications of agile working on the environment) it is difficult to differentiate among local effects and overall impacts. The need for a more complex and critical approach thus arose (Moos et al., 2006), producing different analytical approaches.

On the one hand, the attention of scholars and practitioners focused on the measurement of the reduction of traffic pollutants agile working enabled during the lockdown, as the main proof of its sustainability. In countries that are still largely dependent on private (Fountas et al., 2020) fossil-fed transport solutions, reduced mobility and air emissions are the most evident positive outcome of the agile working.

On the other hand, studies on agile working stopped focussing on work mobility only. Moving from the recognition that commuting is not the only cause of the environmental burden produced by the working activity, an increased number of authors started criticising the idea that agile working automatically produces a positive net balance in GHG emissions: in many cases, the commuting travels avoided by agile working are replaced with others, even more emissive (Moos et al., 2006). The consumption of gas, electric energy, food and consumables that occur during the working activity also produces an environmental pressure that varies according to the way the work is organised.

This approach also considers the substitution and spillover effects that accompany the adoption of agile working. For instance, we observe from the literature that the energy savings allowed by the reduction of daily travels are at least partly counterbalanced by the additional consumption of energy determined by the extra hours spent working at home. Where the workplace is re-designed to reduce space per employee and the worker respect the usual working time of the office then there can be substantial additional energy savings as a result (Banister et al., 2007; Hook et al., 2020).

In 2006, Moos, Andrey and Johnson already claimed for a more comprehensive framework on agile working, capable of considering also how overall lifestyles and behavioural changes translate into a net environmental impact. As the authors observed agile working create far-reaching changes in participants' lives, with potentially important environmental impacts. To say it differently, workers that experience agile working are subject to adjustments in their life-styles affecting numerous consumption categories; but this makes it difficult to assess the overall implications of agile working for the environment (Moos et al., 2006).

An issue still open to the debate – which is here only introduced as a future research agenda – is the possibility that the experience of agile working during the pandemic will push individuals to assume environmentally responsible attitudes. Working from home, could have favoured in the remote workers a higher level of awareness on the costs (energy, consumables etc.) of the working activity and a new attention towards the preservation of the world ecosystem.

3. AGILE WORKING AND TRANSPORT EMISSIONS: ASSESSMENT OF THE CO_2 REDUCTION

Exploiting the COVID "laboratory" (Loia & Adinolfi, 2021; Sen & Al-Habaibeh, 2020), many studies have tried to estimate the reduction of the environmental burden of the working activity allowed by a massive adoption of agile working. Our study aims at contributing to this stream of the literature focussing on a specific type of organization experiencing agile working during the pandemic, i.e. PROs, and a specific type of environmental implication, i.e. the reduction of commuting flows and related GHG emissions.

In order to analyse the implications of agile working in PROs, we focus on the replies to the questionnaire that describes the environmental attitudes of respondents during and after the 2020 lockdown. We quantify the decrease of emissions due to the reduced daily travel of workers during the lockdown and develop a scenario analysis based on their preferences for the future.

The methodology to assess the agile working impact on transport emissions in Italy can be derived from studies about the diffusion of agile working within the Italian economy as well as the European one.

For example, in Germany, Bachelet et al. (2021) showed that the direct effects of an agile working organization for 15% of total work force would reduce 4.5 million tons of CO_2 due to the car commuting decrease. It is about 3% of total CO_2 emissions in transports.

In UK, Banister et al. (2007) show that on average the UK agile worker spend 28 kilometres every day to commute to the office. The distance is higher than the result of the National Census (14 kilometres a day) because of the selection criteria of the agile working employee, as they usually live far from the office. One day a week of agile working would save each year about 217 kilogrammes of CO_2 per capita, due to a CO_2 consumption of 200 grammes of CO_2 per kilometre by car.

Carbon Trust and Vodafone Institute for Society and Communication (2021) studied the characteristics of agile working in six countries (Czech Republic, Germany, Italy, Spain, Sweden and the United Kingdom) by analysing the amount of carbon emissions saved by working remotely before, during and after the first wave of the pandemic.

In the pre-COVID situation it is noted that in some countries the use of agile working was higher than the average (Germany and Spain) while in others it was much lower (Italy). During the lockdown all the indicators went up, and there were huge CO_2 savings. Estimates on post-COVID savings consider the work organization and the energy structure in each country. For example, the savings in commuting depend on the use of the car, which in Italy is higher than in other countries, while the overall savings also depend on the building efficiency of offices and homes. The flexibility of the work organization has a direct impact, too. In fact, it is necessary that the offices can reduce consumption according to the number of people on-site, and that public transports adapt the supply to the changes in the demand. For example, agile working has a positive net effect only if the energy consumption at home is lower than at office.

Otherwise, what you consume at home is added to the fixed consumption you have in the office or in public transport (if you do not use the car for commuting).

Estimates indicate that Italy will have a huge environmental benefit (8.7 million tons of CO_2 saved) if agile working continues to be adopted after the pandemic, thanks to the higher use of cars for commuting, the greater energy efficiency of homes compared to offices, and the lower use of agile working in the pre-COVID situation. This generates a net saving of 1.8 tons of CO_2 per agile worker each year.

In any case, the Carbon Trust & Vodafone report (2021) underlines that their assessment depends on several variables, very difficult to control, as they differ not only from country to country, but also within the same country and city, because the personal habits directly affect the individual saving.

As far as the Italian case is concerned, several studies tried to assess the relationship between agile working and the benefits for the environment (Noussan & Jarre, 2021; Rovetta, 2021). It is difficult to compare them as they propose different methodologies and samples, nevertheless it is interesting to show their results.

The Polytechnic of Milan estimates that the application of 2.5 days per week of agile working will lead to lower emissions of about 1.8 million tons of CO_2 for each agile worker, in addition to the savings of 123 hours in traffic jams, and 1,450 euros in car fees (Politecnico di Milano, 2021).

The report also highlights some critical issues, due to the non-homogenous distribution of this innovative organization: large companies are going to implement agile working at a larger extension in comparison to small firms and Public Administration, because of a lack of managerial culture in the latter.

ENEA (Penna et al., 2020) studied agile working in 29 Italian Public Administrations, involving 3,387 remote workers out of 5,550 total workers, in a pre-COVID period (2015-2018), and it could be considered one of the first extensive studies on this issue.

The study shows that agile workers' houses are pretty far away from the office, as they save about 30 km and 90 minutes of commuting every day. This is mainly due to the sample selection, as the ENEA agile working rules give privileged access to the workers who live the farthest[1]. In the 2015-2018 period, the ENEA report estimates total savings of 46 million of commuting kilometres and 4 million euros of non-purchased fuel. The benefit for the environment is about 8,000 tons of CO_2 reduction in the period.

A study about the workers at the Municipality of Brescia (Gorlani, 2021) shows that 800, out of 1,600 total employees experienced the agile working in 2021. As about 70% of agile workers used to commute by car, making 44 minutes and 21 kilometres of travel every day, the total environment benefit is estimated in 565 tons of CO_2 reduction in a year. On average, they saved 2,9 kg of CO_2 per day, i.e. about 140 gr CO_2 per kilometre, in the commuting.

FORUM PA (2020) made a survey on public employees during the COVID-19 lockdown, to check to what extent the Public Organizations implemented the agile working procedure. As far as the impact of agile working on the environment, the FORUM PA sample shows that workers saved about 90 minutes and 20 kilometres for commuting every day. If only 40% of public employees would work from home for 2.5 days a week, they would avoid 128 million hours of time commuting (made by over 880,000 cars travelling 1 billion of kilometres), saving about 121,000 tons of CO_2 into the atmosphere, and 384 million euros of fuel per year. On average, each worker – aboard on a small car (120 gr per km of CO_2 consumption), for a 20-kilometre round trip – would save 230 euros per month and avoid emitting 72 kg of CO_2.

Bringme – a carpooling startup born in 2011 at the business incubator of the Politecnico di Torino – has quantified that during the COVID-19 lockdown in March and April 2020 its clients saved 90 minutes of commuting time from home to work per capita. On the whole, all the clients saved 10,000 hours of free time and over 60 tons of CO_2 not released in the atmosphere (Rullo, 2020).

Variazioni srl, a consulting company based in Mantova, in a survey involving 850 employees working from home one day per week, estimated at least 40 hours of free time, and 135 kg of CO2 less emitted into the environment each year per worker (Illarietti, 2018).

UBI Bank since 2015 gave to employees the opportunity to work from home, saving per day two hours of commuting, 102 kilometres of driving and 20 euros of costs on average. On the whole, the experience avoided 450,000 kilometres of travel and 50 tons of CO_2 emissions (Castellucci, 2018).

SNPA – the Federation of the Regional Agencies for the Protection of the Environment – is a public organization that in the period March-May 2020 conducted a survey to its employees to assess the benefits of the agile working. SNPA processed a sample of 2,966 questionnaires (out of 10,480 total employees), where 80% of workers drive a car to commute to the office. As SNPA workers spend on average 28 kilometres in commuting, the total amount of CO_2 reduction saved during the March-May 2020 period is about 1,884 tons. This means a saving of 794 kg of CO_2 per capita (SNPA, 2020).

A similar survey was conducted by the Environmental Agency of the Aosta Valley, in 2020 during the COVID-19 lockdown. The results are even more interesting, as they reflect a different kind of society and habits. The survey was about 1,600 workers that spent 46 days in agile

[1] This is the so-called "telelavoro" contract.

working organization. During this period, they saved 1.5 million kilometres of commuting and 386 tons of CO_2, which correspond to 20 kilometres and 2.45 kilograms of CO_2 each day per worker. It represents about 2% of the total amount of CO_2 emissions in the Aosta Valley (Arpa Valle d'Aosta, 2020).

Finally, the INPS study (2021) on the agile working experience of its employees has found a clear direct relationship between the desire to work remotely and the distance home-office. The savings in terms of private expenses, that workers indicated as one of the benefits coming from agile working, could be considered as an environmental saving as well.

Altogether, these studies show the variety of the variables involved in the assessment of the environmental implications of agile working: social habits, labour market characteristics, industrial structure, public transport organizations, structure of consumption, structure of the energy grid, and many other determinants could affect the final results.

For example, the workers' labour contract matters: civil servants (considered in the studies by ENEA, FORUM PA and Politecnico di Milano) have a more rigid contract and governance than private workers (considered in the UBI example). Also, public organizations experienced a great amount of remote workers for the first time in 2020, during the COVID-19 lockdown, whereas the private ones have been already experienced agile working since long, although with a reduced number of workers involved. Therefore, per capita savings in public organizations are higher than in the private sector: in the first case the marginal effects are completely new, in the other case they are just additional.

Secondly, the home-office distance and the efficiency of local public transports are relevant. Office sites in the city centre reduce the commuting time in comparison with office sites in the country, where the number of workers using the car and the home-office distance are high.

Finally, the method for selecting the remote employees is important. When the selection is strict, because only few workers are eligible for the agile working, the worker sample is mainly composed of employees located very far from the office, as the home-office distance is usually a strong criterion for the selection of the available positions. This is why the home-office distance is higher in the UBI bank case, in comparison with the Brescia Municipality one: in the first one, they selected only few workers, using family and location criteria, whereas in other case all the employees were admitted to the agile working. As a result, the CO_2 saving is higher in the first case.

4. RESULTS

The web-based survey analysed in our study investigates the pre-pandemic commuting habits of PROs researchers and technologists (R&Ts), as well as the expected modifications in a future post-pandemic era. The aim is to assess the environmental impact implied by different organizational scenarios, introducing agile working in regular job practices. All tables and figures in this section are authors' elaboration from survey data.

4.1. Commuting costs of a regular research day

This section calculates a very rough cost of commuting in a working day by considering workers' prevalent means of transport, the distance covered, and the usual duration of their travel to work. Table 7.1 summarizes travelling habits of the respondents: the great majority of respondents travels by car (i.e., car/SUV and economy car: 60.4%), covering a shorter distance by using smaller vehicles (29.2 km for economy car vs. 40.6 km for car/SUV). About one worker over five travels by public transports (train, bus, tramway), covering 60 km in one hour and a half round-trip. Electric vehicles are very rare (2.1% of total respondents), whereas short trips are travelled using motorbikes or hybrid vehicles (16 km in half an hour, on average). Finally, 12

workers over 100 are fully eco-friendly, travelling by bicycle or on foot and covering on average 6 km in 25 minutes.

Table 7.1. Summary statistics by prevalent means of transport (per day).

Means of transport	Users (persons)	Users (%)	Travel duration (h)	Average duration (min/pers)	Distance covered (km)	Average distance (km/pers)
Car/SUV	353	12.1%	289.0	49.1	14,322.0	40.6
Economy car	1,412	48.3%	1,009.9	42.9	41,257.1	29.2
Bike/On foot	362	12.4%	150.7	25.0	2,201.3	6.1
Electric vehicle	61	2.1%	44.9	44.1	1,596.0	26.2
Scooter/Motorbike/Hybrid	180	6.2%	96.7	32.2	2,861.1	15.9
Public transport (Train/Metro/Bus)	553	18.9%	900.3	97.7	34,074.4	61.6
Total	2,921	100.0%	2,491.5	51.2	96,311.9	33.0

According to the survey, commuting in a regular pre-pandemic working day burns 51 minutes per person on a 33 km round-trip, and R&Ts totally spend about 2,500 life-hours in the traffic.

As we mentioned in section 3, environmental costs can be estimated in terms of CO_2 emissions. Table 7.2 shows a rough calculation of per day emissions based on CO_2 average emissions per type of prevalent vehicle (column 1, see Section 3): a regular working day in Italian PROs emits 10.3 tons CO_2, equivalent to 3.6 kg per R&T.

Table 7.2. CO_2 emissions by means of transport (per day)

Means of transport	CO_2 emissions (gr/km)	CO_2 emissions (kg)	Average emission (kg/pers)	CO_2 emission std dev
Car/SUV	250	3,400.9	9.8	12.5
Economy car	110	4,424.3	3.2	3.7
Bike/On foot	0	0.0	0.0	0.0
Electric vehicle	43	68.6	1.1	1.2
Scooter/Motorbike/Hybrid	80	228.9	1.3	1.6
Public transport (Train/Metro/Bus)	70	2,224.8	4.1	4.4
Total		10,347.5	3.6	6.0

Note: Emissions are calculated removing outliers (7 Car/SUV, 12 Economy car, 9 Public transport).

According to the survey in section 3, per capita CO_2 emissions are highly in line with other Italian public administrations (FORUM PA, 2020) and very similar to the city of Brescia (Gorlani, 2021) and Aosta Valley. Average distance is akin to ENEA (Penna et al., 2020) and SNPA (2020), but R&Ts travel duration is shorter.

However, Table 7.2 (column 3) shows that differences by means of transport are very relevant: SUV drivers emit about 10 kg per day, 3 times more than a small-car driver; public transport travellers emit 4 kg per day, while motor-bikers, hybrid- and electric-drivers are charged about 1 kg per day. Figure 7.1 shows that 76% total commuting emissions are due to cars (i.e., 33% for car/SUV +43% for economy car) and 21% by public transport; the rest is practically irrelevant.

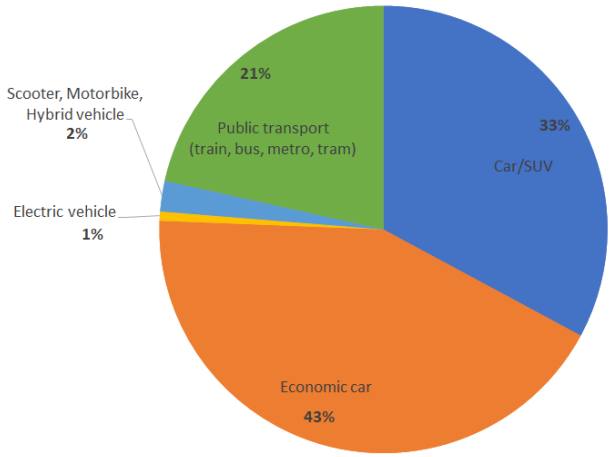

Figure 7.1. CO_2 emissions by means of transport, %.

This is confirmed by Figure 7.2, plotting the frequency distribution of individual commuting emissions per day by prevalent means of transport. Each histogram refers to a different means of transport; the last panel depicts total emissions. Each bin represents an emission class, ranged on the x-axis; the number of users/respondents falling in that specific class is reported on the y-axis. The largest per-day emissions and number of users refer to cars, both SUV and economic ones; then public transport, principally due to long-distance travels. Finally, users and emissions are considerably lower in the case of motorbikes, hybrid and electric vehicles.

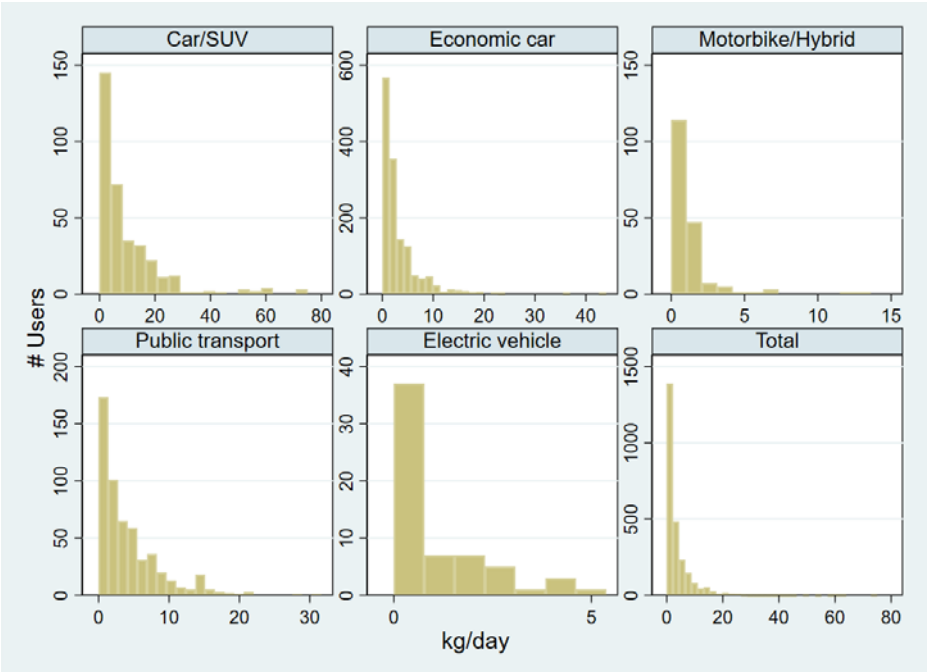

Figure 7.2. Frequency distribution of workers' CO_2 emissions per day by prevalent means of transport.

4.2. Environmental savings: future scenarios of agile working

The pandemic shock forced the whole population of R&Ts to stop commuting and start experiencing agile working. In many cases, adaptation to this new work setting, its tools and practices, was neither immediate nor effortless: about one worker over four declared scarce ability to adapt at the beginning, coupled with a sense of isolation (51.8% respondents) and excessive work-load (37.0%)[2]. By the way, the great majority acknowledges convenience in terms of commuting savings (76.6%) and environmental advantages (50.8%).

Hence: what if agile working is regularly implemented in the post-pandemic era? The previous section roughly estimates per-day savings from commuting: we are talking of about 2,500 hours, 10.3 tons CO_2 emissions and a total distance of one and a half Earth's circumference (i.e., more than 96,000 km). However, the survey points out that, if they can choose, R&Ts would prefer on average 2.1 agile working days per week.

Table 7.3 summarizes savings by prevalent means of transport if each R&T could choose his preferred quantity of agile working per week (from 0 to 5 days). It is evident the positive correlation between desired quantity of agile working and the average time devoted to commute: workers using public transports have the longest trips (98 minutes on average) and would prefer the highest quantity of agile working (2.4 days per week). If implemented, their desired quantity would save 4.2 hours of free time per person, more than double with respect to car users. However, the largest emission savings would concern car users, who are the most numerous and cover the longest total distance.

Table 7.3 – Savings if the desired quantity of Agile working (AW) per individual is implemented (per week).

Means of transport	AW days, average (days per week)	CO_2 emissions savings (kg)	Commuting time savings (h)	Average time savings (h/pers)
Car/SUV	2.2	8,538.9	708.1	2.0
Economy car	2.0	10,154.3	2,294.0	1.6
Bike/On foot	2.0	0.0	335.7	0.9
Electric vehicle	2.1	168.3	104.0	1.7
Scooter/Motorbike/Hybrid	2.0	524.7	216.0	1.2
Public transport (Train/Metro/Bus)	2.4	5,992.5	2,344.9	4.2
Total	2.1	25,378.8	6,002.7	2.1

Preferences about agile working days are quite similar across gender. In particular, 17% workers do not want agile working, but one out three would choose two days per week, and the 37% three or more days (Figure 7.3). If everyone is satisfied, it means 25.4 tons of emissions saved and about 6,000 hours out of the traffic per week, i.e. 2.1 hours per worker.

[2] See Chapter 5 for details on wellbeing analysis.

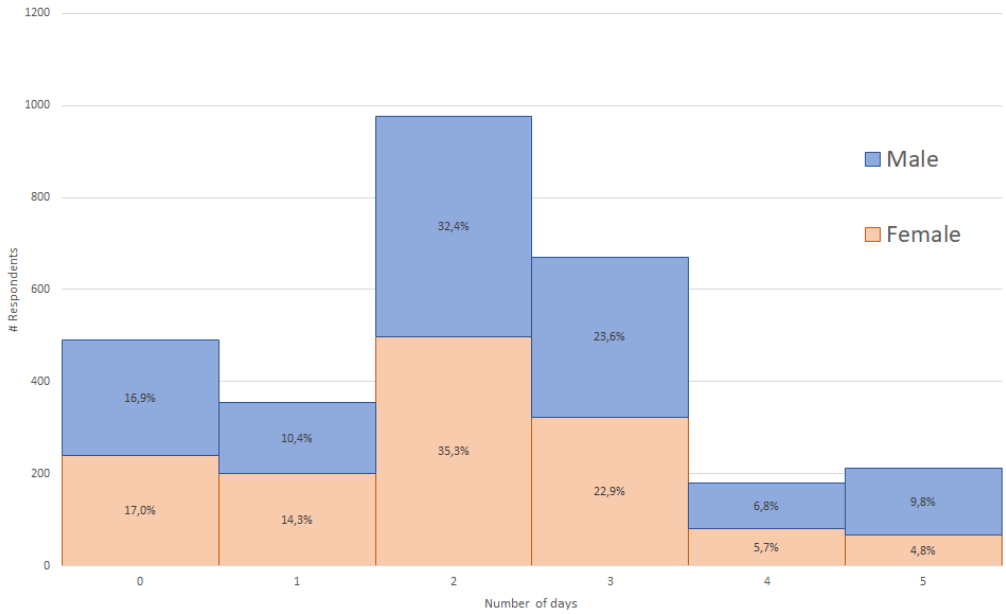

Figure 7.3. Number of agile working days preferred in post pandemic, by gender.

Finally, the pandemic experience itself is expected to produce an impact on workers' habits. Although the expected changes involve a very small fraction of respondents (8.5%), the overall balance favours eco-friendly behaviour. A specific question of the survey referred to the willingness to change habits in means of transport after the pandemic period. Considering these replays, figure 7.4 represents the expected variations in emissions due to the future adoption of a different means of transport (over the same way to work): the horizontal axis describes the actual means of transport, while the vertical axis describes the expected means of transport in the post-pandemic future. Hence, the main diagonal represents stable situations (same emissions), while the upper left matrix represents eco-friendly transitions.

This analysis presents a not so promising result. Considering workers changing from car (car/SUV and economy car) to public transport, the emission saving is about 198 kg (i.e., 112+86), but considering R&Ts that will change their habits from public transport to economy car, the emissions will increase of about 230 kg, then the net impact is an increasing pollution of about 32 kg (i.e., 230-198) per regular day. The situation changes only when considering the increasing adoption of bicycle or foot as commuting means for reaching the workplace. However, we expect an overall net saving of 89 kg CO_2 emissions per regular day, even in the case agile working is completely neglected.

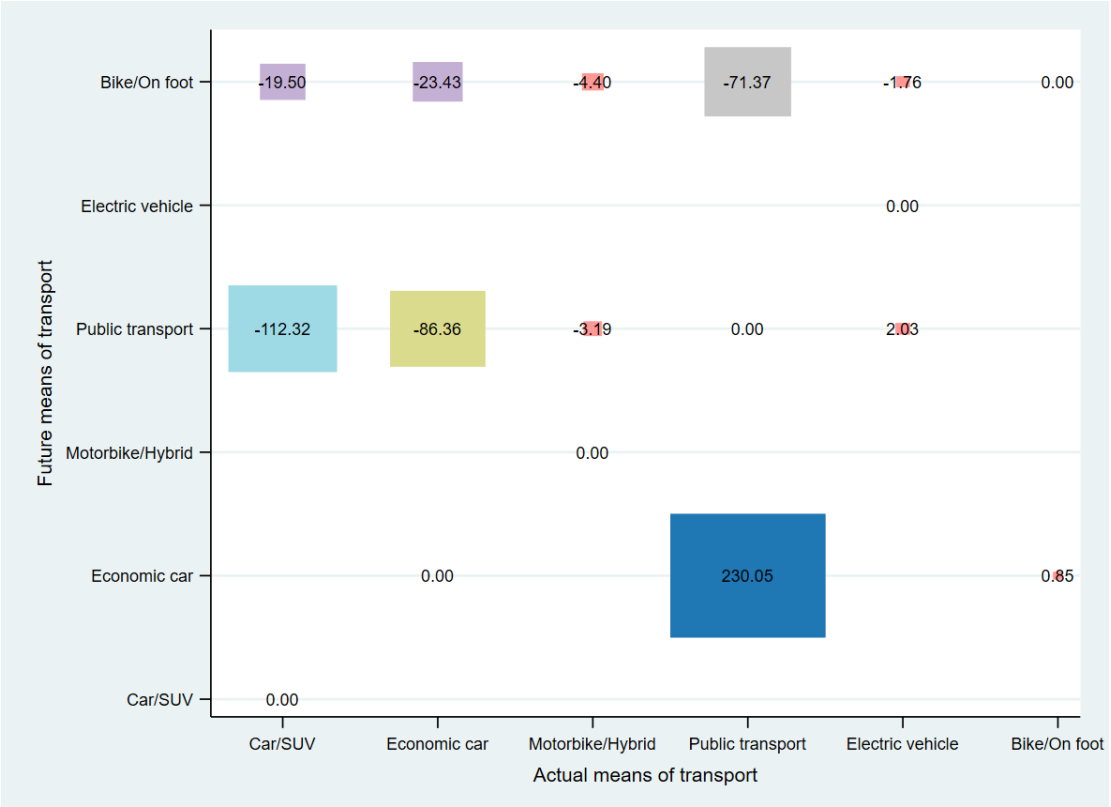

Figure 7.4. Expected variation in means of transport and expected CO_2 savings (kg/day).

5. Conclusions

The pandemic period due to COVID-19 has led to significant changes in the lifestyles of people all over the world and has stimulated the adoption of agile working organization both in the public and in the private sectors.

The results of the present study refer to a survey conducted on a specific typology of Italian workers. Indeed, the working population here analysed concerns scientific research, and, in particular, the Italian Public Research Organizations represented by 2,921 respondents to a questionnaire that has been filled in during the 2021 (see Chapter 2 for details).

The goal of our contribution is to evaluate the agile working effects on commuting habits, highlighting the impact of emission savings.

There are two main questions we have answered in this specific case-study: from the one hand, we have investigated if the agile working has a decreasing impact on transport emissions; from the other hand, we have proposed a simulation on possible future impact of agile working organization in terms of transport emissions.

Starting from survey responses, without agile working and then before the COVID-19 pandemic, the majority of PROs workers (i.e., about 1,800 respondents) travels prevalently by car (i.e., car/SUV or economy car) producing about 8,000 kg of CO_2 emissions per regular day. Considering also R&Ts travelling by public transports (i.e., 550 respondents), the emissions increase of about 2,200 kg per regular day, for a total of 10,200 kg of CO_2.

With the introduction of agile working as usual organizational procedure, the simulation based on the survey answers on the preferred number of agile working days for the post-pandemic period, suggests that we can estimate an emissions' saving of 25,000 kg per week. In addition, the experience of agile working organization during pandemic can change the preferences of PROs workers for transport habits: the questionnaires confirm a small but clear change in future transport habits, as we can expect an additional saving of 89 kg of CO_2 emissions per regular day, i.e. about 450 kg per week. Many PROs workers will change their commuting means from car

(i.e., car/SUV and economy car) to public transport, but, at the same time, many others declare they will reach their workplace by car, leaving the public transport. The evolution towards a larger use of ecologic means of transport is positive but not so strong, and it confirms that the level of public awareness on this environmental potential is not very high, even in a high-skilled population as R&Ts. Recently, Loia & Adinolfi (2021) developed a six-month sentiment analysis of about 11,000 tweets that showed that the ecological value of agile working is not well perceived by people: "surprisingly, in a pandemic context of growing ecological concern, there is no significant evidence of environmental awareness in relation to teleworking".

In any case, a new contract of Italian public administration is going to provide the adoption of agile working in PROs, and from the results of our study, we can expect that this innovation will improve not only the well-being and productivity of workers (see Chapters 4 and 5), but also the environment, reducing the CO_2 emissions due to fewer trips to the workplace and, at the same time, due to the changes in habits of commuting means. These results should be taken into consideration by policy makers because the estimates of emission savings are consistent.

In the perspective of our analysis, a more holistic approach on agile working and its outcomes paves the way to promising future research agendas. Indeed, it is necessary to consider the "net balance" of the agile working impact on the environment and not only the CO_2 savings from the commuting. Several aspects can decrease the environmental benefits due to agile working, as the new household consumptions could be added to the fixed consumption in the office or in public transport. For example, to avoid a reduction in net benefits, the workplace must be re-designed to adapt space and energy consumptions to the varying number of employees. But also, other characteristics of our society have to change to take full advantage from a higher use of agile working, such as the energy efficiency of the houses, the flexibility of the public transports, new business models for bars and restaurants that were previously linked to commuting workers, and so on. All these changes have an impact on the environment and affect the final net balance.

In any case, from the results of the present analysis, we can conclude that the adoption of agile working could have a positive net impact on CO_2 emissions due to fewer trips to the workplace and, at the same time, due to the changes in habit reductions, contributing to the process of ecological transition and sustainability that our societies try to implement.

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