Air Pollution and Job Search Behaviour*

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Abstract

Air pollution is shown to have detrimental effects on health, physical activity and cognitive performance, which are important factors contributing to job search success. This paper studies the impact of fine particulate matter pollution (PM10) on the job search behaviour of unemployed job seekers. We use rich survey data on unemployed job seekers in Germany and exploit quasi-experimental variation in the individual exposure to PM10 pollution based on the random allocation of interviews to individuals. Our results show that high levels of PM10 pollution significantly reduce job seekers' reservation wage. We further provide evidence that PM10 pollution increases job seekers' risk aversion and decreases their search intensity, which may serve as potential mechanisms through which PM10 exposure leads to a reduction in the reservation wage.

Keywords: Air pollution, job search.
JEL codes: Q53, J64.

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1 Introduction

Air pollution significantly impacts our daily lives. A growing body of research shows that exposure to poor air quality leads to a reduction in physical activity levels due to its negative impacts on health (Bhatnagar, 2006; Rückerl et al., 2011) and worker productivity (Graff Zivin and Neidell, 2012; Meyer and Pagel, 2017). In addition, recent studies provide evidence that poor air quality has adverse effects on cognitive functioning, impairing the quality of individuals' performance in cognitive demanding tasks (Ebenstein et al., 2016; Künn et al., 2019). Moreover, high levels of air pollution can also trigger changes in individual risk tolerance and patience (Heyes et al., 2016; Chew et al., 2019; Klingen and van Ommeren, 2020). These studies focus on settings outside of the labour market or have been limited to specific sectors, such as the agricultural, service or sports sector.

This study now investigates the effect of ambient air pollution on the job search behavior of job seekers. There are multiple reasons to believe that the aforementioned adverse effects of air pollution also affect the search behavior of job seekers. Searching for a job is a cognitive demanding tasks during where job seekers are continuously deciding whether or not to accept a job offer based on their reservation wage. Job seekers set this minimal wage level at which they would accept an offer based on their labour market beliefs and search intensity as well as their risk and time preferences (Pissarides, 1974; Mortensen, 1986; DellaVigna and Paserman, 2005). Exactly these determinants of the reservation wage are shown to be influenced by air pollution. Yet, it is unclear whether air pollution exposure indeed leads to meaningful changes in the reservation wages of job seekers.

We provide first evidence on the impact of air pollution on the job search behaviour of unemployed job seekers. Specifically, we examine the effect of ambient particulate matter (PM10)[1] on the hourly reservation wage using rich survey data on unemployed job seekers, who registered as unemployed at the German Federal Employment Agency between June 2007 and May 2008, combined with information on air pollution and meteorological data. Besides detailed information on individual job search behaviour, the survey data contains the exact starting time of the interview allowing us to accurately match the survey data to the pollution and weather data.

We identify a causal effect by exploiting quasi-experimental variation in PM10 concentrations based on the random allocations of interviews to individuals across different counties over time. Individuals are randomly drawn out of a pool of available addresses of workers entering unemployment between June 2007 and May 2008 and called at a random date and time to

[1]Fine particles with a diameter smaller than 2.5 μm (PM2.5) are considered as the most harmful particles for humans, because they can deeply penetrate in the lungs and brain causing inflammatory reaction influencing human health and behaviour. Yet, the small coverage of PM2.5 measures in Germany in the years 2007 and 2008 would substantially reduce our sample size. Therefore, we base our analysis on slightly larger particles with a diameter smaller than 10 μm which are strongly correlated with PM2.5.

participate in a telephone interview about their labour market activities. The idea behind this strategy is that these individuals are randomly exposed to varying levels of PM10 pollution based on the random timing of their interview, allowing us to identify a causal impact of exposure to PM10 concentration on the reservation wage of unemployed job seekers. Additionally, we control for individual characteristics as well as weather conditions and regional factors which might simultaneously affect job search behaviour and air pollution concentrations. A falsification test based on future values of PM10 concentrations as well as results using an instrumental variable strategy exploiting exogenous variation in wind direction and wind speed confirm the validity of our identification strategy.

Our results show that PM10 pollution triggers a reduction in the reservation wages of job seekers. In particular, we find that exposure to an average PM10 concentration above 45 $\mu g/m^3$ during the last 24 hours before the interview lead to a reduction in the reported hourly reservation wage of approximately 3%, compared to concentrations of PM10 below 15 $\mu g/m^3$. Moreover, we find evidence indicating that high levels of PM10 pollution decreases job seekers' risk tolerance as well as their search intensity, which may serve as a potential mechanism through which PM10 exposure leads to a reduction in the reservation wage.

This paper makes the following contributions to the literature. First, while earlier studies on the economic and social impact of air pollution took place in settings outside the labour markets or focussed on the working population, evidence on its impact on the unemployed workforce is still missing. This paper is, to the best of our knowledge, the first to study the impact of PM10 pollution on the search behaviour of unemployed job seekers. Thereby, we complement the growing literature on the social and economic impacts of air pollution exposure. Second, we contribute to the job search literature by examining another potential factor influencing job search behaviour and, in turn, labour market outcomes: particulate matter exposure. Thereby, this study contributes to a broader understanding of external factors influencing job search.

The remainder of the paper is structured as follows. In the next section, we present our conceptual framework linking the impact of air pollution on cognitive performance, preferences and activity levels to job search behaviour. Section 3 describes the data and discusses the empirical strategy. The results are presented in section 4. In this section, we also show several robustness checks and present evidence on the potential mechanisms. Section 5 concludes.

2 Conceptual Framework

2.1 Job Search Behaviour

Job search theory focuses on the reservation wage as main instrument through which unemployed job seekers could influence their job finding probability. This theory describes the process of

unemployed job seekers who are continuously looking for a job under imperfect information and uncertainty about future wage offers (McCall, 1970; Mortensen, 1986; Petrongolo and Pissarides, 2001). Every period job seekers receive a certain amount of job offers depending on the general state of the labour market and their own search effort. The job seeker then decides whether or not to accept this job offer. Following the basic job search model, the job seeker's optimal strategy is to accept a job offer if and only if the discounted utility from being hired for the offered wage is greater then or equal to the discounted utility from remaining unemployed and continuing searching for (better) job offers. The threshold value which makes the job seeker indifferent between accepting the job offer and continuing searching is the reservation wage, which describes the lowest wage at which a job seeker is willing to accept the offer. Thus, the job seeker will only accept a job offer in case the offered wage is above the reservation wage and reject it otherwise. Hence, the reservation wage plays a key role in determining the seekers' probability of finding employment.

Job seekers set their reservation wage based on their labour market beliefs as well as their risk and time preferences. Firstly, job seekers set their reservation wage based on their beliefs about the wage offer distribution and the job offer arrival rate. This is a cognitive demanding task and a general misinterpretation of labour market information by job seekers would result in a wrong assessment of one's labour market opportunities. It has been shown that job seekers tend to overestimate their job offer arrival rate leading to higher reservation wages prolonging their duration of unemployment (Spinnewijn, 2015). In addition, job seekers can influence the job offer arrival rate through their own search effort, where an increase in search effort is likely to result in an increase in the reservation wage through an increased probability of receiving a job offer. Secondly, the job seekers' degree of risk aversion and patience also influences the reservation wage. Job search theory and empirical evidence suggest an inverse relationship between reservation wages and risk aversion (Pissarides, 1974; Pannenberg, 2010). Risk averse job seekers prefer the certainty of being employed and receiving a fixed income. Therefore, they would be willing to decrease their reservation wage to increase their probability of finding a job in the near future. In line with this, impatient job seekers are expected to lower their reservation wage, because they assign a higher value to present benefits compared to future benefits. In addition, impatient job seekers have a lower incentive to invest in the future and are, therefore, more likely to reduce their search effort (DellaVigna and Paserman, 2005). To sum up, job seekers' cognitive ability to evaluate and process labour market information as well as their risk and time preferences, are likely to determine their reservation wage.

2.2 Air Pollution Exposure

Cognitive Performance and Preferences Job search is a cognitive demanding task during which job seekers continuously have to make decisions on the amount of effort they want to exert and whether or not to accept incoming job offers, weighing their current economic situation against their future job prospects. A growing number of studies report harming effects of air pollution on the brain and cognitive performance. The inhalation of particles smaller than 200 nanometers can enter the nose and travel into the brain and lungs, causing systemic inflammatory reactions, damaging the brain and hampering cognition (Calderón-Garcidueñas et al., 2015; Underwood, 2017). These adverse effects on cognition are shown to have severe consequences for the performance of individuals in cognitive tasks (Zhang et al., 2018). Empirical evidence shows that students perform worse in high-stake examinations (Ebenstein et al., 2016) and obtain lower test scores (Roth, 2018) in case of exposure to high concentrations of particulate matter. Moreover, Künn et al. (2019) show that air pollution impairs the quality of individuals' performance in cognitive tasks, in particular when individuals are acting under time pressure. Hence, it is very likely that this extends to the cognitive task of searching for a job. Cognitive decline is likely to exacerbate a general misinterpretation of labour market information by the job seekers, leading to an overestimation of the probability of receiving a job offer and finding a job. Therefore, exposure to higher levels of air pollution is expected to have a negative effect on the search effort as well as the reservation wage of job seekers.

The harming effects of air pollution on cognitive performance are also suggested to affect risk and time preferences, as cognition is shown to be related to risk preferences and patience (Dohmen et al., 2010). Empirical evidence suggests that exposure to air pollution induces a decrease in risk tolerance and patience (Heyes et al., 2016; Bondy et al., 2018; Chew et al., 2019; Klingen and van Ommeren, 2020). This relationship is likely to be mediated by an air pollution induced increase in stress hormones (Li et al., 2017; Niu et al., 2018), which is shown to increase both risk aversion and the subjective discounting rate (Cornelisse et al., 2013; Kandasamy et al., 2014; Riis-Vestergaard et al., 2018). These behavioural changes due to air pollution are likely to affect job search behaviour. Job search theory suggests that risk averse job seekers set a lower reservation wage to increase their job finding probability. Similarly, an increase in impatience is suggested to lower the job seeker's reservation wage. Yet, impatient job seekers are also suggested to lower their search effort, due to a lower valuation of the future benefits of being employed compared to the current costs of searching. Hence, the change in risk and time preferences due to air pollution exposure is expected to have a negative effect on both the search effort and the reservation wage of job seekers.

Health and Productivity A job seeker's search effort could be affected by several factors, such as their cognitive performance and risk and time preferences as discussed above. In addition, the physical ability to search for a job also affects a job seeker's search effort, such as the job seeker's health and level of productivity. Accumulating evidence shows that elevated levels of ozone and particulate matter are associated with cardiovascular and respiratory diseases (Bhatnagar, 2006; Brunekreef and Holgate, 2002; Rückerl et al., 2011). In addition, exposure to particulate matter can also lead to milder adverse health effects, such as asthma episodes, elevated blood pressure and headaches (Ghio et al., 2000; Pope III, 2000). Especially these milder adverse health effects of air pollution exposure may restrict an individual's physical activity level.

This is supported by numerous studies reporting negative effects of air pollution on workers' effort and physical productivity. Evidence from physically demanding occupations shows a significant negative impact of air pollution on the productivity of workers (Graff Zivin and Neidell, 2012; Chang et al., 2016; Lichter et al., 2017; Archsmith et al., 2018). Yet, a large number of jobs held in western countries involve office work rather than physical demanding work. Therefore, recent literature started to explore the effect of air pollution on the productivity of office workers, showing that higher levels of particulate matter also decrease the productivity of semi-skilled office worker through a decrease in uptime (Meyer and Pagel, 2017), an increase in judges' decision time (Kahn and Li, 2019) and an increase in the amount of time spent on breaks (Chang et al., 2019). These negative productivity effects are not likely to be limited to the working population. Also unemployed individuals are likely to experience a drop in their effort and physical productivity level due to air pollution exposure. Hence, it is expected that unemployed job seekers experiencing a rise in air pollution concentrations decrease their search effort, which negatively affects their job offer arrival rate and, in turn, lowers their reservation wage.

Job search behaviour The discussion above suggests that exposure to air pollution is likely to affect job seekers' search behaviour. Figure 1 illustrates the potential mechanisms through which particulate matter pollution affects the reservation wage. Empirical evidence shows that particulate matter has a negative effect on cognition, risk and time preferences, as well as the activity level. Job search theory suggests that all of these behavioural aspects (in)directly affect the job search behaviour of unemployed individuals. Overall, the effect of air pollution on the reservation wage is expected to be negative. Job seekers are expected to lower their search effort due to air pollution exposure, resulting in a lower probability of receiving job offers and, in turn, a lower reservation wage. Furthermore, particulate matter pollution negatively affects cognitive performance, risk tolerance and patience, and is, therefore, expected to lower the reservation wage.

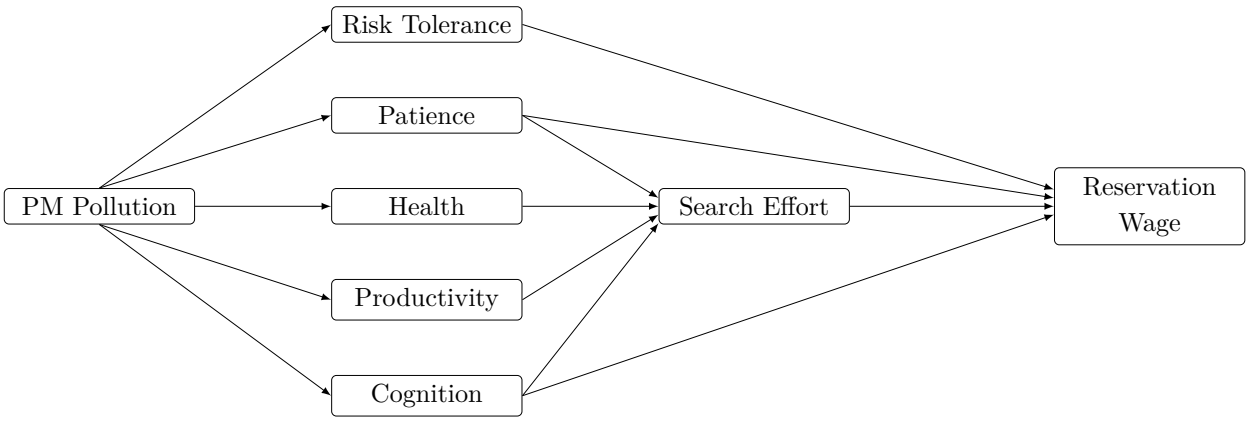


Figure 1: The effect of air pollution on job search behaviour

3 Data and Empirical Strategy

3.1 Data

The empirical analysis relies on extensive survey data on job search behaviour which is combined with data on local air pollution and weather conditions. First, we use the *IZA Evaluation Dataset Survey*, which comprises survey information on 17,396 individuals who entered unemployment between June 2007 and May 2008 (see Arni et al., 2014, for details on the data).[2] The first interview took place shortly after entry into unemployment (on average 10 weeks). A second and third interview took place after 12 and 36 months, respectively. Besides an extensive set of socio-demographic and household characteristics, the survey contains information about labour market histories. Most important, the data set provides detailed information on individuals' job search behaviour as well as their risk preferences and degree of patience. In addition, we observe the exact date and time of the interview which allows us to accurately link the survey responses to the pollution and weather data.

Second, the pollution data is provided by the German Federal Environment Agency (*Umweltbundesamt*). It comprises geo-coded hourly measures of ground-level concentration of multiple pollutants from several measuring stations. Our measure for air pollution is the hourly concentration of particulate matter with particles smaller than ten micrometers (μm) in ambient air (PM10). Particulate matter is a mixture of solid and liquid particles with different compositions that vary in size, which are mainly generated by construction or traffic. In addition, we merge ozone (O3) levels which emerge from photochemical reactions of nitrogen oxide stimulated by the sun's ultraviolet light, and can be considered a proxy for general air pollution.

Third, since weather conditions are important environmental confounders of air pollution, we further include a rich set of weather controls provided by the German Meteriological Service (*Deutscher Wetterdienst*). Temperature, humidity and wind speed are measured as 24-hour

[2]The survey data can be accessed via the International Data Service Center (IDSC) of the Institute of Labor Economics (IZA).

averages, whereas precipitation is measured as the total amount over 24 hours. In addition, we extract hourly data on wind direction.

We link the survey, pollution and weather data based on the date and time of the interview and county centroid. Specifically, the pollution values are linked to the survey participants by calculating the inverse distance-weighted averages for the pollution and weather measures across all monitoring stations within a certain radius from the centroid of the participants' county of residence. The choice of the radius comes with a trade-off between the accuracy of the measurement within a county and the number of observations that will be included in our analysis due to the absence of monitors close to county centroids. Taking this trade-off into account, we chose the 30 kilometre radius for our main analysis. In addition, we test the sensitivity of our results to this radius by estimating our main specification using the pollution and weather measures taken within a radius of 20km from the county centroid.

For the purpose of the study, we impose the following restrictions to the dataset. We use the first wave of the IZA Evaluation Dataset Survey only, because of a large reduction in the number of observations in the second and third wave which would significantly reduce the statistical power of the empirical model. Furthermore, we restrict the analysis to unemployed individuals who report that they are searching for employment as only they received the questions on job search behaviour. This leaves us with an estimation sample comprising 9144 individuals who reported their reservation wage. Next, we link the survey data with the weather and pollution measures and we exclude observations with missing information on any of our control variables. Our final dataset comprises 6858 individuals for whom we can analyse the effect of air pollution on their reservation wage.

Table 1 reports the descriptive statistics of the main variables in the dataset. We have a balanced sample of men and women who were, on average, 35 years old. The individuals in our sample were on average unemployed for 63 days before their first interview and the majority experienced a previous unemployment spell and receive unemployment benefits. Furthermore, we observe substantial variation in their reported reservation wage during the interview. Finally, the descriptive statistics on the ambient concentrations of PM10 [3] and O3 indicate a strong variation in air pollution exposure during the last 24 hours before the interviews which we exploit in our empirical analysis.

3.2 Study Design and Identification Strategy

Our goal is to estimate the effect of PM10 pollution on the reservation wage of unemployed job seekers. Therefore, we need to accurately link the reported reservation wages to PM10

[3]Figure A.1 in the Appendix presents the full distribution of the mean concentrations of PM10 the last 24 hours before the interview.

Table 1: Descriptive statistics

	Mean	SD	Min	Max	N
Reservation wage	7.20	4.17	0.01	189.87	6.858
Pollution data					
PM10 ($\mu g/m^3$)	23.52	12.19	1.36	113.59	6.858
O3 ($\mu g/m^3$)	43.82	22.61	0.85	141.52	6.858
Weather data					
Temperature ($°C$)	9.51	6.35	-9.83	24.67	6.858
Relative humidity (%)	77.55	9.66	39.64	99.43	6.858
Wind speed (m/s)	3.59	1.62	0.10	14.77	6.858
Precipitation (mm)	2.27	3.93	0	51.71	6.858
Individual characteristics					
Age	35.15	10.56	17	55	6.858
Female	0.51	0.50	0	1	6.858
Partner	0.70	0.46	0	1	6.858
Children	0.33	0.47	0	1	6.858
Migration background	0.21	0.41	0	1	6.858
Vocational education	0.64	0.48	0	1	6.858
Higher education	0.15	0.36	0	1	6.858
Previous unemployment spell	0.69	0.46	0	1	6.858
Previous employment full time	0.64	0.48	0	1	6.858
Last income	1,055.51	1,010.94	0	39,000.00	6.858
Unemployment benefit receipient	0.80	0.40	0	1	6.858
Days of unemployment	63.44	26.20	25	150	6.858

Notes: This table displays the descriptive statistics for the estimation sample. Pollution and weather measurements are computed based on a radius of 30km.

concentrations that unemployed job seekers were exposed to just before the interview. The interviewed job seekers were asked to report their marginal minimum wage for which they would be willing to work as well as the number of hours they think they would have to work for this wage. Hence, they reported the hourly reservation wage they had at the exact time of the interview. This snapshot of their reservation wage together with the availability of the exact starting time of the interview allows us to accurately match the reported reservation wage with the air pollution concentration measured in the county of residence just before the interview.

Figure 2 illustrates how the reported reservation wage is linked to the pollution and weather indicators. We match the observed average of PM10 concentrations 24 hours before the interview with the reported reservation wage to allow for a potential lagged effect of PM10 pollution. In this example, Individual A is interviewed on October 24 in 2007 at 10:00 AM. Thus, we match the calculated average concentration of PM10 pollution from October 23 at 10:00AM to 10 o'clock

at October 24 to the reported reservation wage. The same is done for the weather controls using a weighted average of the daily values based on the randomly allocated hour of the interview.

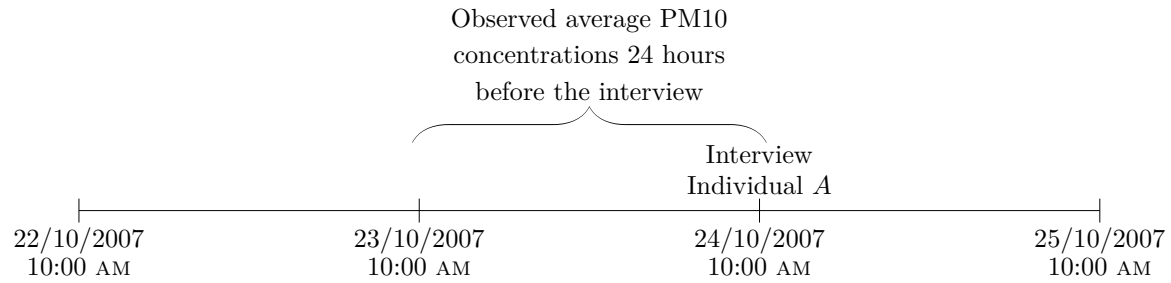


Figure 2: Study design

This study design allows for a causal interpretation, because we can exploit quasi-experimental variation in PM10 concentrations due to the random allocation of interviews to individuals across different counties over time. Following this strategy, we can identify a causal effect under the assumption that the variation in PM10 pollution is as good as random across the different interview dates and counties. First, the interviewed job seekers are resident in different counties in Germany which are all subject to different levels of air pollution. This allows us to exploit spatial variation in the exposure to PM10 pollution around the time of the interview. Second, we exploit temporal variation in PM10 concentrations. Our observed individuals are randomly drawn out of a pool of available addresses of individuals entering unemployment between June 2007 and May 2008. Moreover, the unemployed job seekers are called at a random date and time to participate in the interview.[4] This ensures a random exposure to PM10 concentrations during the interview within their county of residence.

There are several potential challenges to our causal identification strategy. First, local economic activity could be correlated with both the level of air pollution exposure and the reservation wage of job seekers. We address this challenge by showing regressions with PM10 concentrations before and after the time of the interview as a falsification test. The underlying thought is that the levels of air pollution after the interview should not affect the answers given during the interview. In addition, we instrument for PM10 concentrations with the variation in wind direction and wind speed at the day of the interview to further test the robustness of our estimates to potential confounding factors. The falsification test as well as the IV estimation confirm the validity of our identification strategy. Second, individuals might not be available for the interview at the time of the random call. In that case, they could reschedule the call to a different date and time. These appointments are a potential threat to our identification strategy. Yet, our robustness check shows that restricting the sample to individuals without a fixed appointment does not lead to any significant changes of the results.

[4]Individuals who do not answer their phone are returned to the pool of potential subjects and will be contacted again at another random point in time.

3.3 Regression Model

To exploit the spatial and temporal variation in PM10 concentrations, we follow a fixed effects strategy and estimate the following regression model,

$$Y_{ij} = \alpha + \beta f(PM10_j) + \delta X_{ij} + \gamma M + \mu W_j + \nu R_j + \eta_s + \epsilon_s, \quad (1)$$

where the dependent variable, Y_{ij}, is the hourly reservation wage of individual i in county j measured in natural logarithms. We measure our variable of interest $PM10_j$ as a step-wise linear function of mean PM10 concentrations 24 hours before the interview. Specifically, we create different categories for every 10 $\mu g/m^3$ of PM10, with concentrations below 15 $\mu g/m^3$ as the reference category and concentrations above 45 $\mu g/m^3$ as the highest category. The vector X_{it} controls for individual (labour market) characteristics and R_{jt} contains regional control variables. We further control for the month, day of the week and hour of the interview (M). In addition, we control for weather and environmental conditions, W_j, which are shown to influence both PM10 concentrations and individual behaviour. Last, we include state fixed effects, η_s, and cluster the standard errors at the state level, ϵ_s.

The relationship between the reservation wage and exposure to PM10 concentrations is measured by β, our parameter of interest. In this analysis, we exploit the exogenous variation in the survey respondents' exposure to particulate matter. Hence, our main identifying assumption is that concentrations of PM10 are randomly assigned to the individuals after including all control variables and state fixed effects. Thus, in this study the parameter is identified based on the random timing of the interview generating variation in PM10 exposure between individuals within the different counties.

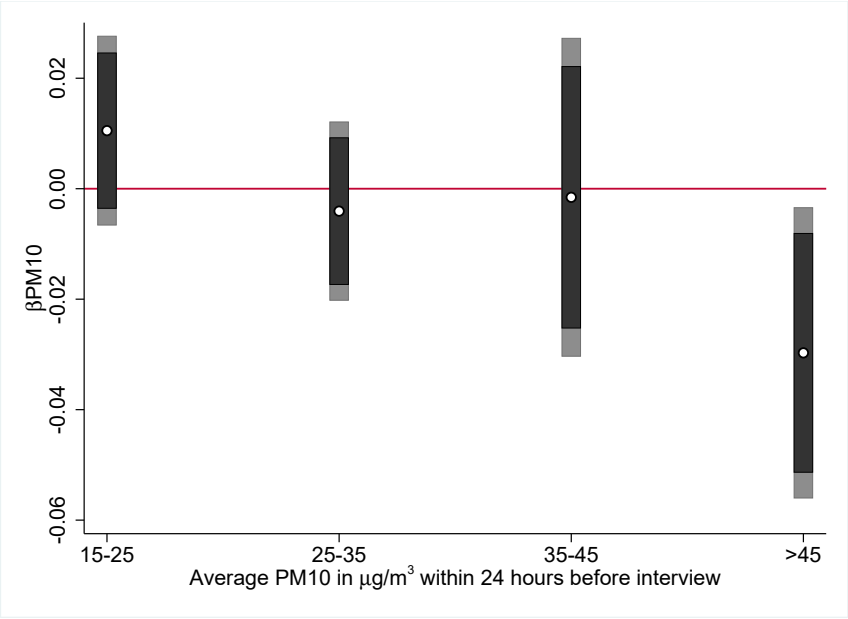
4 Results

In this section, we present the results on the impact of air pollution on the job search behaviour of unemployed job seekers. First, in section 4.1, we show the results on the effect of PM10 pollution on the reservation wage. The sensitivity checks are presented in section 4.2, and section 4.3 examines potential mechanisms through which PM10 pollution could affect the reservation wage.

4.1 Reservation Wage

Figure 3 presents the estimated coefficient $\hat{\beta}$ showing the relationship between the exposure to the different categories of PM10 and the hourly reservation wage. We find a significant negative effect of exposure to PM10 concentrations above 45 $\mu g/m^3$ on the reservation wage, indicating a reduction in the hourly reservation wage of approximately 3%, compared to the reference category. We find no effect of lower concentrations of PM10 pollution on the reservation wage.

Figure 3: Reservation Wage in natural logarithm [N=6858]



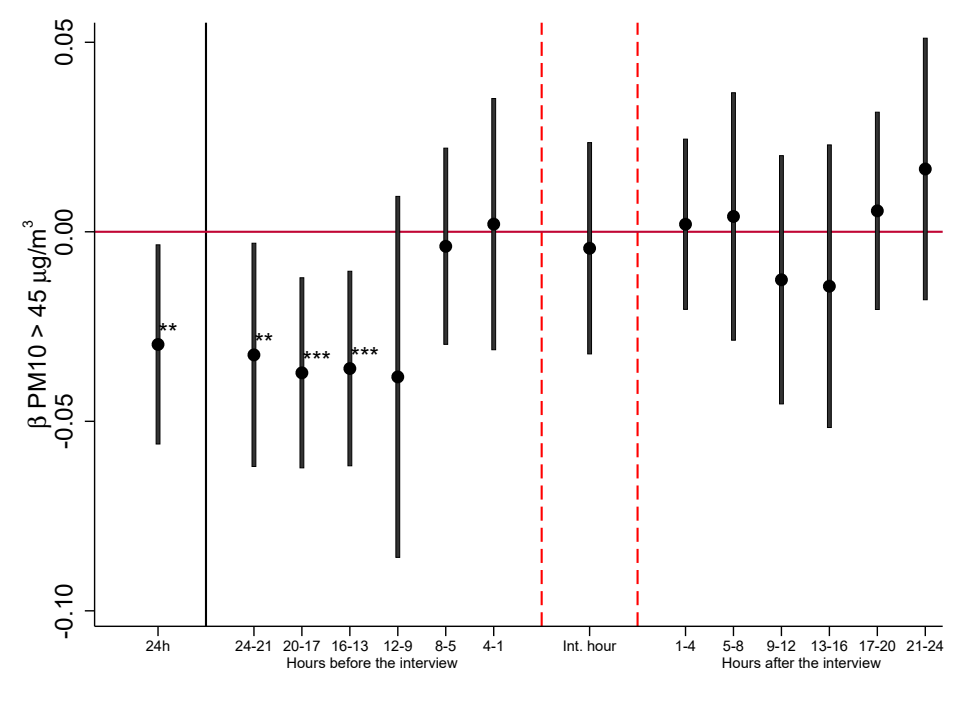
Note: Dots represent point estimates. Reference group: Days with PM10 pollution below 15 $\mu g/m^3$. Black (gray) bars show the 90% (95%) confidence intervals calculated based on standard errors clustered at the state level. All regressions include the full set of fixed effects and control variables.

4.1.1 Lagged and Lead PM10 Values

We further examine the relationship between PM10 pollution and the reservation wage by taking a closer look at the timing of the effect. In particular, we focus on the highest category of PM10 concentrations above 45 $\mu g/m^3$ while controlling for the other categories of PM10 pollution. We estimate a modified version of equation (1), varying the time of measurement of PM10 concentrations from 24 hours before the interview to 24 hours after the interview in intervals of 4 hours. The coefficients displayed in Figure 4 are the result of separate regressions, where the estimated coefficient on the left corresponds to the estimate of PM10 concentrations exceeding 45 $\mu g/m^3$ in Figure 3. We find no evidence of a direct effect of PM10 pollution during the exact hour of interview on the reservation wage. Yet, we do observe a significant effect of PM10 concentrations between 13 and 24 hours before the interview on the reservation wage. Hence, the negative effect of exposure to high PM10 concentrations on the reservation wage is likely driven by a lagged effect of approximately half a day.

Furthermore, we conduct a falsification test by examining the effect of PM10 concentrations after the interview on the reported hourly reservation wage. The underlying thought is that future concentrations of PM10 should not affect the answers given during the interview. Indeed, we find no evidence of a relationship between PM10 concentrations measured after the interview and the reported reservation wage. The absence of an effect for lead PM10 concentrations supports that our results are not driven by unobserved confounding factors.

Figure 4: Lagged and lead values PM10



Note: The graph shows the estimated coefficient of separate regressions with a 95% confidence interval based on the clustered standard errors. */**/*** indicate statistical significance at the 10%/5%/1% levels.

4.2 Sensitivity Analysis

In addition to the falsification test, we present a number of sensitivity tests to further assess the robustness of our significant results. In particular, we re-estimate the stepwise-linear model as shown in equation (1), introducing the following modifications: (i) We restrict the sample to individuals without an appointment for the interview. (ii) We use pollution and weather measures taken within a smaller radius from the county centroid. (iii) Finally, we perform an instrumental variable analysis to further test the robustness of our estimates.

4.2.1 Appointments

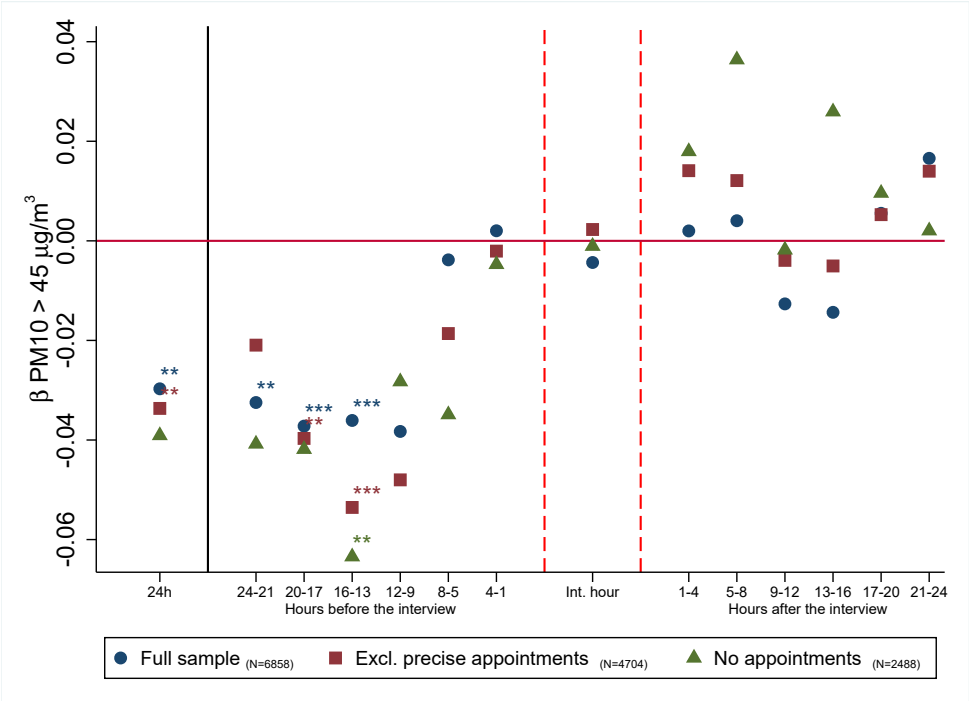
Our main identifying assumption is based on the random timing of the interview. The individuals in our sample are randomly drawn out of a pool of available addresses and called for an interview. Hence, our subjects were not aware of an interview coming up and could not influence its timing. Yet, some individuals who answered the phone were not available for the interview at the time of the random call. They were allowed to reschedule the call to a different date and time, which threatens the validity of our main identifying assumption. Therefore, we test the sensitivity of our estimates to the randomness of the call by restricting our sample to individuals without a fixed appointment.

Figure 5 presents the results of this sensitivity check. It illustrates the estimates of the effect of PM10 concentrations above 45 $\mu g/m^3$ on the hourly reservation wage for three different

samples. The sample illustrated by the ◯ symbol corresponds to the full estimation sample. In contrast, the sample illustrated by the △ symbol is restricted to individuals without an appointment. This restriction ensures that all individuals in the sample are interviewed at a random date and time, but it also significantly reduces the number of observations, and hence the precision of our estimates. Therefore, we consider a third sample, illustrated by the □ symbol, that excludes individuals with concrete appointments, but includes individuals with vague appointments. These individuals, for example, mentioned that they would be available for the interview during an evening or a particular day of the week without specifying the exact date or time. Hence, the timing of their interviews could still be regarded as somewhat random.

The estimates suggest that the results presented in section 4.1 are not driven by individuals who made an appointment for the interview. We find a significant negative effect of PM10 concentrations half a day before the interview on the reported reservation wage in all three specifications of our sample. Moreover, the absence of an effect for lead PM10 concentrations in the restricted samples provides further support to the robustness of our estimates to unobserved confounding factors.

Figure 5: Robustness to interview appointments



Note: The graph shows the estimated coefficient of separate regressions with a 95% confidence interval based on the clustered standard errors. */**/*** indicate statistical significance at the 10%/5%/1% levels.

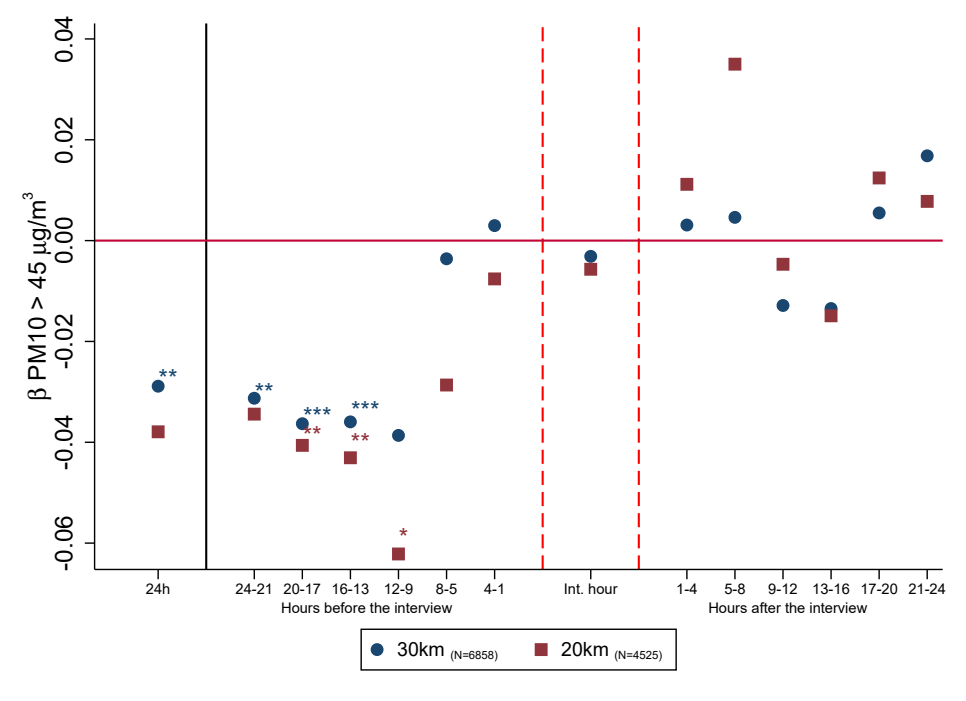
4.2.2 Radius to Monitor

Next, we test for the sensitivity of the results to our chosen radius of 30km from the county centroid to the pollution and weather monitors. We re-estimate equation (1), using a smaller

radius of 20km from the county centroid. This smaller radius yields a more accurate measurement of pollution and weather conditions at the time of the interview, but it also significantly reduces the amount of observations in our sample.

Figure 6 displays the estimates using the 30km and 20km radius. We find a similar pattern for the coefficients based on the 20km radius, compared to our main results using the 30km radius. This finding supports the robustness of our estimates to the choice of the radius from the county centroids to the pollution and weather monitors.

Figure 6: Distance to monitor



Note: The graph shows the estimated coefficient of separate regressions with a 95% confidence interval based on the clustered standard errors. */**/*** indicate statistical significance at the 10%/5%/1% levels.

4.2.3 IV Estimation

In addition to the sensitivity tests presented above, we perform an instrumental variable analysis to further assess the robustness of our results. In particular, we exploit the exogenous variation in wind direction and wind speed around the time of the interview to address two main challenges of our analysis: omitted variable bias and measurement errors. First, although we include a rich set of control variables, our estimates might be biased by confounding factors that simultaneously affect the concentrations of PM10 and the reservation wages of job seekers, such as the level of economic activity in the different regions. Second, we assumed that the exposure to air pollution was similar for all individuals living in a given county. Yet, environmental conditions are not likely to be uniformly distributed within counties, thereby generating measurement error.

To address these potential challenges, we perform an instrumental variable estimation ex-

ploiting the variation in wind direction and wind speed. These environmental conditions are considered as exogenous to human behaviour and local conditions, thereby satisfying the independence condition. The intuition behind this instrument is that both wind direction and wind speed transport PM10 emissions across space affecting the level of air pollution in a given location. In general, downwind areas should have higher pollution levels compared to areas upwind. For example, areas to the west of pollution sources are exposed to higher levels of air pollution on days when the wind blows from the east than on days with wind from the west. Moreover, this relationship between wind direction and air pollution concentrations is influence by the prevailing wind speed. Low wind speeds decrease the transportation distance of air pollutants and, therefore, reduce the effect of the wind direction on PM10 pollution. In contrast, higher wind speeds would strengthen the association between wind direction and PM10 concentrations, because of a greater dispersion of air pollutants to downwind areas. Hence, we define our instrument as an interaction term between the wind direction and wind speed to account for the effect of both wind conditions on the level of PM10 pollution.

Specifically, we instrument PM10 pollution with an interaction term between the fraction of hours during which the wind blew from a 'dirty' direction and the average wind speed 24 hours before the interview. This instrument is constructed in the following way. First, we determined the 'dirty' wind direction by regressing the daily averages of PM10 concentrations from the year 2000 to 2019 on a rich set of weather controls, month-by-year fixed effects and 24 wind direction dummies, each representing a 15-degree interval, for each county separately. The largest resulting estimates for the wind direction dummies represent the 'dirty' wind direction, which is the wind direction associated with the highest level of PM10 concentrations over a timespan of 20 years. Using this specification of the 'dirty' wind direction, we calculated the fraction of hours the wind blew from this 'dirty' direction during the last 24 hours before the interview to construct the first part of our instrumental variable. Second, we calculated the average wind speed as a weighted average of the observed mean values of the daily wind speed 24 hours before the interview. Last, we interact the fraction of hours the wind blew from a 'dirty' direction with the average wind speed. This leaves us with the following specification of our first-stage regression,

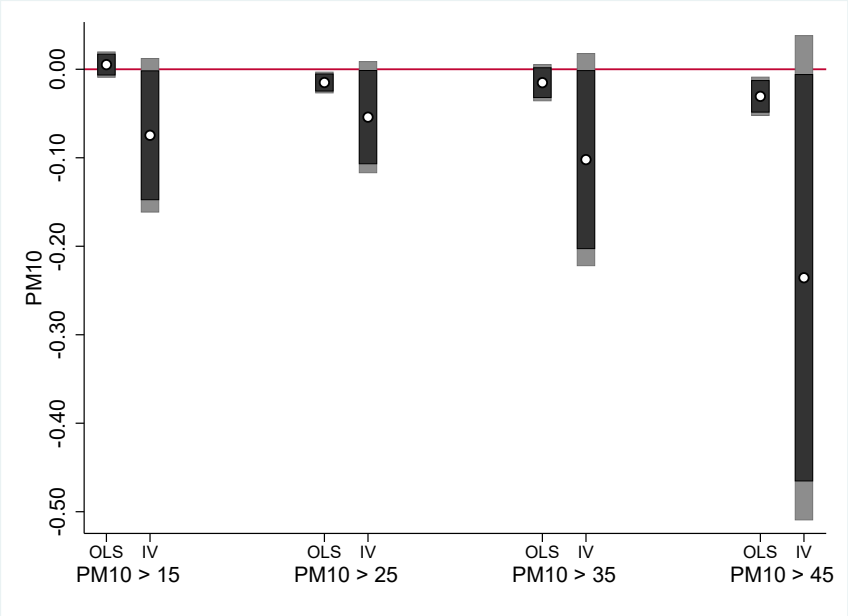
$$PM10_j = \theta DIR_j \times SPEED_j + \kappa DIR_j + \lambda SPEED_j + \phi X_{ij} + \tau M + \psi W_j + \zeta R_j + \upsilon_s + \xi_s, \quad (2)$$

where the outcome variable, $PM10_j$, is measured as a dummy variable taking the value 1 if the concentration of PM10 exceeds a certain threshold and 0 otherwise.

The first-stage regression, equation (2), estimates the degree to which our instrument predicts the level of PM10 concentrations. The second-stage uses these predicted values to estimate the impact of PM10 pollution on the reservation wage. The estimates are presented in Figure 7, where the left bars always represent the OLS estimates and the right bars always depict the estimates

from our instrumental variable analysis. The first-stage F-statistics for the separate regressions range from 35.58 to 181.5, with the largest statistic for the specification of PM10 above 25 $\mu g/m^3$, indicating that our instruments are sufficiently strong. The IV estimates are considerably larger compared to the OLS estimates, suggesting an underestimation of the effect in our main analysis. Focussing on the IV estimates, we find a clear negative effect of exposure to PM10 concentrations on the reservation wage, except for the dummy specification indicating PM10 concentrations above 25 $\mu g/m^3$. Moreover, our results show a clear non-linear pattern, where we find the strongest effect of PM10 concentrations above 45 $\mu g/m^3$ compared to concentrations of PM10 below this threshold. We view these results as supportive evidence of our main results showing a negative impact of PM10 exposure on the reservation wages of unemployed job seekers.

Figure 7: IV Estimation Reservation Wage



Note: The graph shows the estimated coefficient of separate regressions. The dots represent point estimates. Reference group: Days with PM10 pollution below 15 $\mu g/m^3$. Black (gray) bars show the 90% (95%) confidence intervals calculated based on standard errors clustered at the state level. All regressions include the full set of fixed effects and control variables. */**/*** indicate statistical significance at the 10%/5%/1% levels.

4.3 Potential Mechanisms

The PM10 induced reduction in the reservation wage could be triggered through an effect of PM10 pollution on the job seekers' risk and time preferences as well as their search activity. Job search theory suggests a negative effect of risk aversion, impatience and a low search intensity on the reservation wage, as discussed in section 2. Moreover, empirical evidence shows a negative effect of PM10 pollution on these determinants of the reservation wage. In this section, we test our hypothesis that these behavioural aspects could serve as a potential mechanism through which PM10 concentrations trigger a reduction in the reservation wage.

4.3.1 Risk and Time Preferences

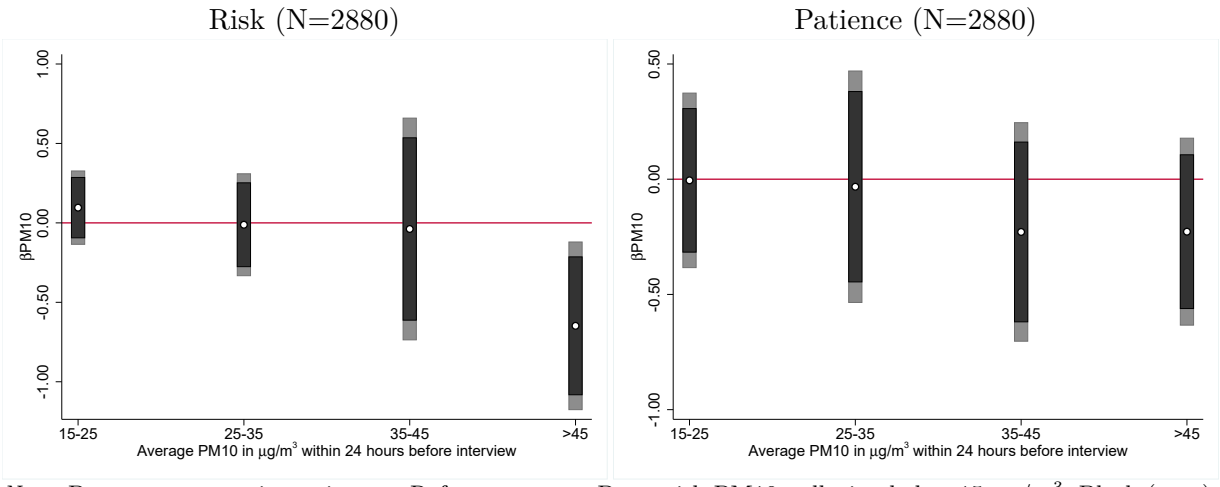
First, we test our hypothesis that exposure to high concentrations of PM10 has a negative effect on one's degree of risk tolerance and patience. For this, we use two question from the *IZA Evaluation Dataset Survey* that were asked to a subsample of three cohorts of survey respondents, corresponding to 25% of the full sample. These individuals were asked to self-report their general willingness to take risks on a scale from 0 (not willing to take risks) to 10 (very willing to take risks), which is shown to be a good predictor of the actual risk behaviour of individuals (Dohmen et al., 2011). Similarly, the respondents were asked to grade themselves with respect to their degree of patience on a scale from 0 (very impatient) to 10 (very patient). Importantly, the respondents report their perception of their risk preference and patience at the randomly allocated time of interview. Hence, similarly to the analysis on the reservation wage, we can accurately match the average concentrations of PM10 24 hours before the interview with the reported preferences.

To examine the effect of PM10 pollution on risk preferences and patience, we estimate a modified version of equation (1) excluding the vector R_j and including a different set of individual controls. Furthermore, we do not restrict our analysis to unemployed individuals searching for unemployment because of sample size limitations. Instead we control for their employment status at the time of the interview.

Figure 8 presents the corresponding results. The left panel shows a significant negative effect of exposure to PM10 concentrations above 45 $\mu g/m^3$ on risk tolerance. This indicates that individuals who are exposed to high levels of PM10 concentrations report themselves to be more risk averse, compared to individuals who are exposed to levels of PM10 below 15 $\mu g/m^3$. According to job search theory, risk averse job seekers tend to reduce their reservation wage to increase the probability of finding a secure job in the near future. Hence, the PM10 induced reduction in risk tolerance could serve as a potential mechanism for the negative effect we observe of PM10 concentrations exceeding 45 $\mu g/m^3$ on the reservation wage.

The panel on the right displays the relationship between the exposure to PM10 concentrations and the reported level of patience. We find no evidence of an effect of PM10 pollution on patience. Hence, the reduction in the reservation wage is not likely to be driven by a PM10 induced reduction in patience.

Figure 8: Mechanisms



Note: Dots represent point estimates. Reference group: Days with PM10 pollution below 15 $\mu g/m^3$. Black (gray) bars show the 90% (95%) confidence intervals calculated based on standard errors clustered at the state level. All regressions include the full set of fixed effects and control variables.

4.3.2 Search Intensity

Second, we examine the relationship between PM10 pollution and the search intensity of unemployed job seekers. The survey respondents reported their number of applications sent since entry into unemployment, which we use to construct our measure of search intensity. The measurement period since entry into unemployment does not allow for a precise match between the reported number of applications and PM10 concentrations the job seeker was exposed to while searching for employment, because we do not observe the exact time and date when the applications were sent. Therefore, we construct a crude match between PM10 pollution and the reported search intensity by calculating the average value of PM10 since entry into unemployment, as illustrated by Figure 9. This measure allows us to explore the relationship between exposure to PM10 concentrations and the search activity of unemployed job seekers.

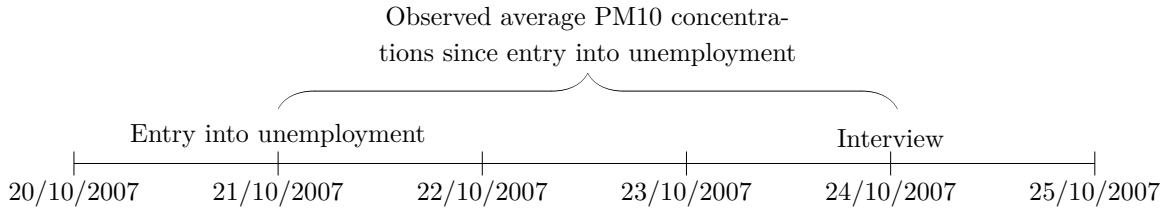


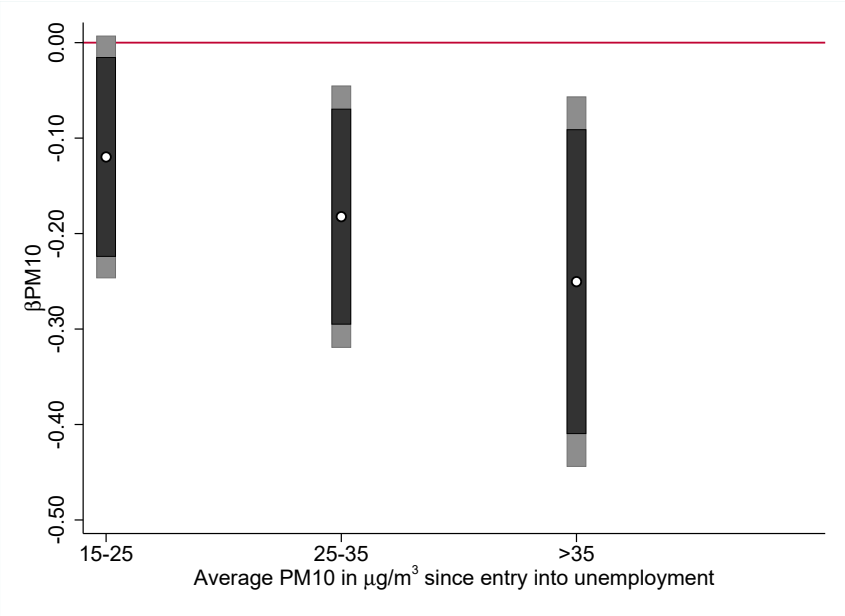
Figure 9: Matching PM10 with the reported search intensity

We re-estimate equation (1) where the outcome variable, Y_{ij}, is the average daily number of applications sent since entry into unemployment measured in natural logarithms. We measure our variable of interest, $PM10_j$, as a step-wise linear function of the average concentration of PM10 since entry into unemployment. In this case, we consider only four categories of PM10 with the highest category being PM10 concentrations above 35 $\mu g/m^3$, because we lose some

variation in the upper part of the distribution of PM10 pollution by taking the average over a longer period of time.

Figure 10 shows the estimated coefficients with respect to the average number of applications sent since entry into unemployment. We find a clear negative relationship between PM10 pollution and the number of applications sent, which is already very significant for lower concentrations of PM10. The magnitude of this effect becomes more pronounced for higher concentrations of PM10, where we find the largest effect for concentrations of PM10 above 35 $\mu g/m^3$. Specifically, exposure to concentrations of PM10 above 35 $\mu g/m^3$ is associated with a decrease of approximately 22% in the average daily number of applications sent, compared to the reference category. Hence, our results suggest that the effect of PM10 on the search intensity of job seekers might serve as a potential mechanism through which PM10 induces a reduction in the reservation wage.

Figure 10: Search Intensity in natural logarithm [N=7186]



Note: Dots represent point estimates. Reference group: Days with PM10 pollution below 15 $\mu g/m^3$. Black (gray) bars show the 90% (95%) confidence intervals calculated based on standard errors clustered at the state level. All regressions include the full set of fixed effects and control variables.

5 Conclusion

In this paper, we analyse the impact of air pollution on job search behaviour. In particular, we examine the effect of particulate matter (PM10) on the reservation wages of unemployed job seekers. Using rich survey data combined with air pollution and meteorological data, we identify a causal effect by exploiting quasi-experimental variation in PM10 concentrations based on the random allocation of interviews to unemployed job seekers across different German counties over time. Thereby, this study contributes to existing literature on the social and economic impacts

of air pollution, which so far only focused on settings outside the labour market or on the working population. In addition, we contribute to the job search literature by broadening our understanding of external factors influencing job search.

We find that exposure to elevated levels of air pollution lead to a reduction in the reservation wages of unemployed job seekers. To our knowledge, this is the first evidence that the negative impacts of air pollution extend to the unemployed workforce. Our estimation results show that exposure to PM10 levels above 45 $\mu g/m^3$ trigger a reduction of approximately 3% in the hourly reservation wage, compared to exposure to concentrations of PM10 below 15 $\mu g/m^3$. Moreover, we find that this effect is likely to be driven by the negative impacts of PM10 exposure on job seekers' risk tolerance and search intensity.

Our results indicate that the negative effects of air pollution exposure are not limited to the working population, but also have important implication for the unemployed workforce. The implications of the PM10 induced reduction in the reservation wage are likely to be twofold. On the one hand, a lower reservation wage is expected to have a positive effect on the probability of finding employment. On the other hand, a reduction in the reservation wage might lead to individuals being pushed into lower paid jobs, causing them to become at risk of being persistently low paid. Moreover, it might increase the risk of repeated unemployment due to a lower job match quality. Based on a separate descriptive analysis using a large sample of entries into unemployment using administrative data, we find suggestive evidence that exposure to elevated PM10 concentrations during unemployment leads to faster unemployment exits, which would be consistent with the hypothesis that a lower reservation wage increases the probability of finding employment. However, we do not find any significant effects of PM10 pollution on wages based on the descriptive analysis using the administrative data. Future research should further investigate the effects of air pollution exposure on the job search outcomes of unemployed job seekers to enhance our understanding of the implications of air pollution for one of the most vulnerable groups in the labour market.

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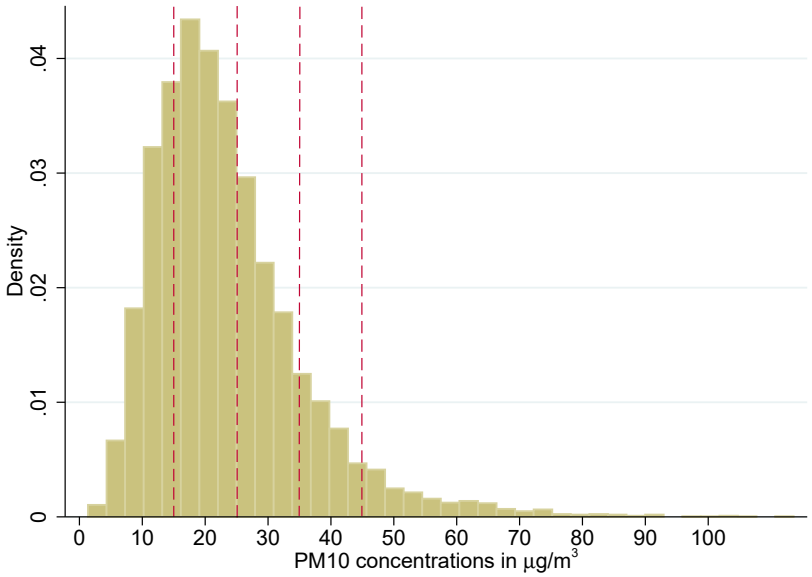
Tables and Figures

A Appendix (for online publication)

Figure A.1: Distribution of mean PM10 concentrations 24 hours before the interview



Note: The red lines indicate the different categories of PM10 used in our analysis.