How Selective Migration Shapes Environmental Inequality in Germany: Evidence from Micro-level Panel Data

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ABSTRACT
Socio-economically disadvantaged and ethnic minorities are affected by a disproportionately high exposure to environmental pollution. Yet, it is unclear if selective migration causes this disproportionate exposure experienced by low-income and minority households. The study uses longitudinal data from the German Socio-Economic Panel to investigate the process of selective migration and its connection to the perceived exposure to air pollution in Germany. Consistent with the selective migration argument, movers experience a decrease in exposure according to their income, whiles stationary households do not experience a reductive effect due to income. Furthermore, the moving returns differ by minority status. While native German households experience less exposure to pollution when moving to a new place of residence, minority households do not. Additional analyses show that this minority effect cannot be explained by socio-economic differences, but completely vanishes in the second immigrant generation.

KEYWORDS
Environmental Inequality; Environmental Justice; German Census; Spatial Analysis (SLX); Spatial Spillover Effects; GIS

1. Introduction

Environmental inequality, connecting the distribution of environmental hazards to socio-economic and ethnic characteristics, has received growing attention in the United States (for an overvew: Mohai and Saha, 2015a; Pellow and Nyseth Brehm, 2013; Ringquist, 2005), as well as in continental Europe (Diekmann and Meyer, 2010; Funderburg and Laurian, 2015; Havard, Deguen, Zmirou-Navier, Schillinger and Bard, 2009; Kohlhuber, Mielck, Weiland and Bolte, 2006; Laurian and Funderburg, 2014; Padilla, Kihal-Talantikite, Vieira, Rossello, Le Nir, Zmirou-Navier and Deguen, 2014). Most of the empirical research focuses on the question whether there is an unequal distribution of environmental pollution; yet only a few studies explore the causal mechanisms. To our knowledge, only one study investigates these causal mechanisms of environmental inequality in continental Europe (Funderburg and Laurian, 2015), exclusively using aggregated data. This is a major shortcoming, as the United States is a rather special case with a high level of economic inequality (Piketty and Saez, 2014) and residential segregation (Musterd, 2005). Therefore, it is far from clear whether we can observe similar drivers of environmental inequality in Europe.

Previous studies, especially from the United States, have identified two causal mechanisms of environmental inequality: selective siting and selective migration (Mohai and Saha, 2015a). The first mechanism states that the increase of pollution follows already existing differences in the socio-demographic composition of neighbourhoods. Hazardous facilities are disproportionately sited in areas with low socio-economic resources and high minority shares (or disproportionately cleaned up in areas with high socio-economic resources and low minority shares). In contrast, the second mechanism assumes that differences in the socio-demographic neighbourhood composition emerge after pre-existing differences in pollution. This means that minority households and households with low socio-economic resources selectively move into polluted areas, while socio-economically advantaged households move out. Previous studies have investigated these two causal explanations on aggregated levels, such as neighbourhoods, zip code areas, or census tracts (Been and Gupta, 1997; Downey, 2005; Funderburg and Laurian, 2015; Mohai and Saha, 2015b; Oakes, Anderton and Anderson, 1996; Pastor, Sadd and Hipp, 2001; Richardson, Shorty and Mitchell, 2010; Shaikh and Loomis, 1999). Those macro-level studies offer mixed results regarding selective siting and provide only weak evidence regarding the selective migration mechanisms. However, the only two longitudinal studies on the household level find evidence for selective migration patterns (Crowder and Downey, 2010; Pais, Crowder and Downey, 2014). Thus, it remains unclear whether selective migration causes the disproportionate exposure to environmental pollution experienced by low-income and minority households.

The present study adds to the discussion of environmental inequality in two ways. First, the present study is the first panel study on environmental inequality in Germany. Hence, we add new evidence to the question, whether selective migration causes environmental inequality in continental Europe. We argue that the exposure to environmental pollution depends on income and ethnic origin via individual moving decisions (selective migration). Secondly, we compare different immigrant groups (first- and second-generation immigrants and by country of origin) and analyse whether the disadvantage of ethnic minorities can be explained by their lower socio-economic status.

This study relies on household-level data of self-reported impairment through air pollution of the German Socio-Economic Panel (GSOEP) between 1986 and 2014. By using panel data and fixed-effects estimators, we ensure that our results are not af-

fected by differing perception of pollution between the households. Though the micro-level data used in this study offer clear advantages when analysing selective migration patterns, they do not allow to investigate selective siting, as the latter depends on aggregated neighbourhood characteristics rather than individual household characteristics.

2. Theory and Previous Results

Numerous studies in the United States have shown that income and race are related to the amount of environmental pollution (for an overvew: Mohai and Saha, 2015a; Pellow and Nyseth Brehm, 2013; Ringquist, 2005). In the German-speaking area, previous studies conclude that low-income households as well as ethnic minorities experience a higher exposure to environmental pollution (Bolte and Mielck, 2004; Diekmann and Meyer, 2010; Kabisch and Haase, 2014; Kohlhuber et al., 2006; Raddatz and Mennis, 2013).[1] Regardless, all these studies did not aim to analyse the causal mechanisms of environmental inequality. Therefore, the following outline of the causal mechanisms mostly relies on literature from the United States.

The selective migration argument assumes that the patterns of environmental inequality result from specific decisions on the individual or household level (Massey, 1990; Schelling, 1978). On the one hand, these residential choices are driven by individual preferences, e.g. the preference to live in a clean and unpolluted environment. On the other hand, individuals have to deal with the structural constraints of their actions. If we assume a similar preference for clean environment throughout the society — an assumption that our analytical strategy allows to relax — market or other allocation mechanisms regulate the access to scarce resources. When selecting a place of residence, individuals try to satisfy their preferences regarding the good 'clean environment', given their economic and structural constraints (Tiebout, 1956). Thus, we have to explain how these constraints differ by income and ethnicity to understand the causes of environmental inequality. First, we will outline how income affects the migration process and afterwards turn to the ethnic differences in migration patterns.

2.1. *Income as the Key to Clean Neighbourhoods*

The 'market explanation' of environmental inequality considers a clean environment as an economic luxury good, which is available on the market for an additional price. Environmental quality influences the rents and housing prices: While housing opportunities in low-quality areas are relatively cheap, they are relatively costly in high-quality areas. As a result, tenants and homebuyers must pay for high environmental quality when making a migration decision (Banzhaf and McCormick, 2012; Been and Gupta, 1997; Diekmann and Meyer, 2010; Hanna, 2007; Hunter, White, Little and Sutton, 2003). Given the preference for a clean environment, households experiencing an increase in income are able to pay more for environmental quality when migrating and consequently will end up in neighbourhoods with lower pollution. Even if housing prices are not exogenously higher in clean neighbourhoods, prices should rise due to higher demand for housing in these areas, despite relatively constant housing opportunities (Banzhaf and McCormick, 2012; Kim, Campbell and Eckerd, 2014). On the other hand, higher environmental pollution (combined with an out-migration of the

[1] Supplementary cross-sectional analyses of our data confirm these results (see Supplementary Table SA1).

wealthier inhabitants and decreasing demand for housing) leads to decreasing housing prices in polluted areas and consequently attracting lower-income households who cannot afford the luxury good 'clean environment'. As a result, lower-income households will choose neighbourhoods with higher pollution when moving.

Following this market explanation, high pollution does not need to be the reason for out-migration. Even if households relocated for other reasons, high-income households sort into clean neighbourhoods, while low-income households sort into polluted neighbourhoods (Banzhaf and McCormick, 2012). Though pollution may trigger out-migration, all migrating households — independent of the reasons for relocation — need to choose a neighbourhood destination, which is assumed to happen selectively.

Therefore, we postulate the following Hypothesis 1:

H1: An increase in income will lead to decreasing exposure to environmental pollution when moving to a new neighbourhood.

This is a causal formulation of the between hypothesis, that is high-income households will on average realize a stronger reduction in exposure. In line with this hypothesis, the majority of previous research has found a negative correlation between income and environmental pollution within the same spatial area (Ash and Fetter, 2004; Downey, 2006; Downey and Hawkins, 2008; Mohai and Saha, 2007; Pastor, Sadd and Morello-Frosch, 2002), which supports the 'market explanation'. Despite this, other studies suggest that there is no relationship between income and environmental pollution (Been and Gupta, 1997; Morello-Frosch and Jesdale, 2005) or at least no linear relationship (Ash, Boyce, Chang and Scharber, 2013; Havard et al., 2009). Aside from these macro-level studies, only two studies have presented results from longitudinal analyses on the micro-level. Crowder and Downey (2010) used household-level data from the Panel of Income Dynamics and pollution data of the Toxics Release Inventory (TRI). They state that although pollution does not increase the probability of out-migration when controlling for other individual characteristics, income is associated with lower pollution in the neighbourhood of destination for movers. Thus, they find a conditional effect of income on pollution. If households move, higher-income households sort into neighbourhoods with a lower amount of pollution. Using similar data, Pais et al. (2014) compare different migration trajectories separated by the exposure to pollution. They find that the probability of being in a constantly high pollution trajectory compared to being in a constantly low pollution trajectory decreases with income. This indicates that households with higher income are more likely to continuously live in low pollution neighbourhoods.

2.2. *Minority Status as a Barrier to Clean Neighbourhoods*

Turning to the disadvantages of ethnic minorities, two explanations have been widely discussed by previous scholars: the 'racial income-inequality thesis' and the 'racial residential discrimination thesis'.[2]

The 'racial income-inequality thesis' relates to the 'market explanation' in explaining the effect of ethnicity on the exposure to environmental pollution (Been and Gupta, 1997; Campbell, Peck and Tschudi, 2010; Crowder and Downey, 2010; Oakes et al., 1996; Pais et al., 2014). Hereafter, the high exposure of ethnic minority groups is not a

[2]The terms 'race' and 'ethnicity' have the same meaning throughout this article. US scholars typically study inequalities based on race, while European researchers typically focus on inequalities along ethnic lines. For our purposes, both concepts refer to a fixed actor attribute that can be the basis for different housing market opportunities.

result of ethnicity itself, but rather, a result of the differences in the socio-economic resources of different ethnic groups. The hypothesis assumes that ethnic minority groups hold a relatively low income compared to the ethnic majority. Following the 'market explanation', minority groups are limited by their economic resources and cannot afford the housing prices in high-quality neighbourhoods. Thus, they are pushed to more affordable but more polluted areas. The ethnic majority, in contrast, holds a relatively high income and faces lower economic constrains when choosing a neighbourhood of destination. It follows that majority households sort into high-quality neighbourhoods, while minority households sort into low-quality neighbourhoods. If this is true, a higher exposure of minority households should dissipate after controlling for socio-economic resources.

In contrast, the second mechanism assumes a persisting effect of ethnicity on the exposure to environmental hazards, independent of socio-economic characteristics. The 'racial residential discrimination thesis' explains the unequal distribution of environmental pollution by discriminating actions of real estate agents or property owners (Crowder and Downey, 2010; Crowder, Pais and South, 2012; Pais et al., 2014; for discrimination on the housing market in general: Choi, Ondrich and Yinger, 2005; Ondrich, Ross and Yinger, 2003; Pager and Shepherd, 2008; Turner and Ross, 2005). The reasons for housing discrimination could be twofold: first, native inhabitants could perceive minority groups as a threat due to prejudices about their criminal behaviour (Massey and Denton, 1993; Semyonov, Grodzeisky and Glikman, 2012). Housing agents and property owners, in turn, fear declining desirability of neighbourhoods and, as a result, declining profits due to minority in-migration (Turner and Ross, 2005; Yinger, 1986). Thus, they prefer majority households as new inhabitants in high-quality neighbourhoods. Secondly, housing agents could spuriously anticipate the housing preferences of minority groups (Ondrich et al., 2003; Turner and Ross, 2005). If housing agents supposed minority groups have lower preferences for clean environments or neighbourhood quality in general, they could pre-select housing offers based on their prejudiced viewpoint. In both cases, discriminating behaviour sorts minority households into polluted neighbourhoods.

The theoretical explanations as well as the empirical results regarding the disproportionate exposure of minority groups stem mainly from the United States and refer to ethnic minorities like Asian, Mexican, or African-American groups. It is important to note that minorities in Germany are the result of relatively recent immigration, mainly from Turkey, Southern Europe, and later Ex-Yugoslavia and Eastern Europe (see Kalter and Granato, 2007, and the more detailed discussion of our data in the following section). Additionally, housing segregation by ethnic group is lower in Germany than in the United States (Musterd, 2005). Nonetheless, we assume that the mechanisms discussed above are transferable to the German context, as previous research has found general disadvantages of immigrants on the German housing market (Auspurg, Hinz and Schmid, 2017; Drever and Clark, 2002), plus a higher exposure of immigrant minorities to pollution (Diekmann and Meyer, 2010 for Switzerland; Kohlhuber et al., 2006; Raddatz and Mennis, 2013 for Germany).

Altogether, this leads to the Hypothesis 2:

H2: Native Germans will realize a stronger reduction in the exposure to environmental pollution than immigrant minority households when moving to a new neighbourhood.

Based on the discussion of the fine-grained mechanisms of selective migration, we will extend our analysis of selective migration in two ways. First, we will test whether

the differences between ethnic groups can be explained by socio-economic differences (H2a: 'racial income-inequality hypothesis'). If this explanation is true, the disadvantage of minorities should disappear or at least diminish when controlling for income. Secondly, we will separate the minority group into first- and second-generation immigrants. If discrimination causes the disproportionate burden of minority households (H2b: 'racial residential discrimination thesis'), we would assume second-generation immigrants to experience similar disadvantages as first-generation immigrants.

The disproportionate exposure of ethnic minorities to environmental pollution is well documented in previous research. Even after controlling for income, many studies document a significant correlation between ethnic minority share and environmental pollution within the same neighbourhood (Ash and Fetter, 2004; Downey, 2006; Downey and Hawkins, 2008; Pastor, Morello-Frosch and Sadd, 2005). In addition, housing audit studies highlight the persisting discrimination against minorities on the housing market (Choi et al., 2005; Ondrich et al., 2003; Turner and Ross, 2005). This income-independent effect of ethnicity is in line with the 'racial residential discrimination thesis'. Yet, as most of the environmental inequality studies use cross-sectional data, they cannot — and do not aim to — identify the causal mechanisms leading to the disproportionate exposure of minority groups to environmental pollution. Nonetheless, some other studies (Been and Gupta, 1997; Downey, 2005; Mohai and Saha, 2015b; Oakes et al., 1996; Pastor et al., 2001; Richardson et al., 2010; Shaikh and Loomis, 1999) focus on the causal mechanisms by analysing longitudinal data on the aggregate level. Of these studies, only Richardson et al. (2010) find empirical evidence for the selective migration into polluted areas. All other macro studies rather contradict the selective migration argument.

In contrast, the two longitudinal studies on the household level find evidence for selective migration of ethnic groups. According to Crowder and Downey (2010), ethnic minorities are more likely to move into polluted areas when comparing mobile households. Even when controlling for socio-economic characteristics, the effect of ethnicity persists. Additionally, the analysis shows that income is a greater determining factor for Black than for White homeseekers in dictating the pollution at the place of destination. This finding is in line with the explanation of discriminating housing markets, as mobile minority households require a higher income to realize the same level of pollution than their majority counterparts do. The second household-level study by Pais et al. (2014) comes to similar conclusions. Although the race effect is lowered in magnitude when controlling for socio-economic factors, the odds of following a high-to-high pollution trajectory are still substantially higher for Black than for White households. These results support both the 'racial income-inequality thesis' and the 'racial residential discrimination thesis'. Furthermore, the number of inter-neighbourhood moves reduces the probability of being in a constantly high-pollution trajectory for White households, while having a contradicting effect for Black households.

3. Data, Operationalization, and Method

We use household-level data from the GSOEP, a repeated and representative panel study in Germany (Wagner, Frick and Schupp, 2007). Our final sample comprises information on 12,037 households, participating between 1986 and 2014. This sample includes all households living in private households (households living in hostels or retirement homes were excluded) participating at least in two of the six relevant waves

(unbalanced panel). All models were estimated without using sampling weights.[3]

As dependent variable we use the subjectively perceived impairment through air pollution. In 1986, 1994, 1999, 2004, 2009, and 2014, the GSOEP household questionnaire included the question 'How strongly do you feel you are affected by the followed environmental influences on your residential area: Through air pollution'. Respondents had to evaluate their answer on a five-point scale ranging from 'Not at all' to 'Very strongly' (coded 15).

The main explanatory variables are income and minority status. As we argue that the latter variables are crucial for the extent of environmental exposure only when people move, we include an interaction-term of these main explanatory variables with a dummy indicating a relocation of the household between two points of observation. This ensures that the report of perceived pollution temporally follows the relocation, and we do not run into trouble concerning the causality. As a measure of income, we calculated the equivalized household income by dividing the monthly net income by the square root of the household size (Burniaux, Dang, Fore, Förster, Mira D'Ercole and Oxley, 1998).

In the German context it makes sense to specify minority as immigrant minority: the vast share of minorities — especially of minorities visible by their looks or their language — are immigrants and their descendants (Kalter and Granato, 2007). Most of the first-generation immigrants in our sample originate from countries covered by Germany's active labour immigration policy of the 1960's like Turkey ($n = 348$), Yugoslavia ($n = 199$), Italy ($n = 171$), Greece ($n = 110$), or Spain ($n = 66$). The second important group of first-generation immigrants originates from Eastern Europe ($n = 566$). In total, the sample contains 1,490 first- and 699 second-generation immigrants.[4] Third-generation immigrants are categorized as native Germans in the original data set. Due to the low number of cases, we need to collapse some of the origins and differentiate between Turkey, former Yugoslavia, and the following regions as classified by the United Nations Statistics Division: Southern Europe, Eastern Europe, rich Western Countries (Northern and Western Europe, the United States, Canada, Australia) and a residual category for other countries (see Gresch and Kristen, 2011, for a discussion of different operationalizations).[5]

Finally, the relocation of the household is measured by three period dummies indicating the first, second, or third move of a household. Hence, the coefficient of the second move-dummy indicates the additional effect of a second move over the first, etc. For construction, all GSOEP waves between 1986 and 2014 were taken into account to capture relocations between the waves used in the final analyses.

Additionally, we include several variables controlling for confounders. Most importantly, we exclude the possibility of a perception bias and, consequently, a spurious decrease in the perception of environmental pollution after a relocation (e.g. due to cognitive-dissonance reduction). Hence, we include a control variable for households

[3]As panel attrition may be an issue for the present research question, we estimated additional models using inverse staying probability weights (not shown). These models yield very similar results (see Solon, Haider and Wooldridge, 2015, for a discussion on weighting).

[4]To separate the effect due to relocation from the effect of other events, we had to exclude 198 households (approximately 1.6 per cent of the total sample) that experienced a change in minority status due to a change of the household head (32 additional households had to be excluded when differentiating between first and second generation of immigration).

[5]Our operationalization of minority status follows the status of the GSOEP household head. This decision ignores the individual migration histories of all other household members. However, our approach avoids questionable exclusions (of mixed native and immigrant households) and leads to more conservative estimates, i.e. a bias towards a non-finding.

that have been living in their new home for less than 6 months. We also include a dummy that captures the change of the household head as perception of pollution might differ between the former and the new household head. In addition, several control variables may influence the pollution level as well as income and thus confound the effect of income on pollution: we include age squared, since income and living situation might notably improve in early adulthood (the linear age term is omitted because it cannot be separated from the year trend in two-way fixed-effects models) but stagnate or decrease in old age. In the same line, we control for children living in the household, considering children influence the household income (by definition) and might influence the residential choice when households move.[6] Since we are interested in the total effect, we generally do not control for mediators. An important exception is controlling for income when testing the 'racial income-inequality hypothesis'.

To identify the causal mechanisms of environmental inequality, we use fixed-effects panel estimators. These estimators use the variance within the household over time while excluding the variance between the households (Allison, 2009; Brüderl and Ludwig, 2015). Time-constant household-specific characteristics are excluded and no longer affect the estimation results. Furthermore, the inclusion of year-dummies (two-way fixed-effects) ensures that people without relevant within-variance — households without any relocation — serve as a control group. This controls for a change in pollution level over time independent of our explanatory variables. For ease of interpretation, we use linear fixed-effects estimators, though the dependent variable is measured on an ordinal scale. To ensure that this model selection does not influence our results, we conducted additional sensitivity checks using an additive index of air and noise pollution[7] as well as fixed-effects ordered-logit models (see Supplementary Tables SA2 and SA3). Both models fully support the results of the linear fixed-effects estimators of air pollution.

4. Results

Table 1. Summary Statistics

	Native German household		Minority household	
Variable	Mean	SD (within)	Mean	SD (within)
Per cent moved at least once	49.04		63.76	
Perceived impairment through air pollution	1.825	0.587	1.923	0.639
Per cent experienced an improvement	48.62		49.62	
Monthly equivalence income (in 1,000 Euros)	1.614	0.527	1.367	0.426
Age of household head	52.683	5.928	48.963	6.088
Children living in household	0.263	0.273	0.379	0.296
Nuber of households	9,816		2,221	
Obseervations	31,267		7,118	

Table 1 presents descriptive statistics by the household's minority status. First, the data show that most households report a low perceived impairment through air pollution (mean of 1.8). Secondly, the data indicate a higher mobility level for minority

[6]Note that we do not include control variables that might cause moving decisions. This would be important if we investigated the question whether pollution induces relocations. However, for our dependent variable the reasons for the moving decision do not confound the results.

[7]The subjective impairment by ambient noise was measured using a question very similar to air pollution (see above).

Table 2. Fixed-effects estimation of perceived impairment through air pollution

	FE 1	FE 2	FE 3	FE 4
HH equiv inc in t	−0.008		−0.009	−0.009
	(0.009)		(0.009)	(0.009)
1. Move	−0.203***	−0.282***	−0.247***	−0.249***
	(0.030)	(0.022)	(0.031)	(0.032)
2. Move	−0.034	−0.080**	−0.039	−0.045
	(0.039)	(0.025)	(0.042)	(0.042)
3. Move	−0.014	−0.015	−0.023	−0.034
	(0.086)	(0.041)	(0.087)	(0.088)
1. Move × HH equiv inc in t	−0.027*		−0.022	−0.021
	(0.013)		(0.013)	(0.013)
2. Move × HH equiv inc in t	−0.019		−0.020	−0.018
	(0.020)		(0.020)	(0.020)
3. Move × HH equiv inc in t	0.009		0.009	0.014
	(0.044)		(0.044)	(0.045)
1. Move × Minority=1		0.165***	0.159***	
		(0.044)	(0.044)	
2. Move × Minority=1		0.023	0.015	
		(0.049)	(0.049)	
3. Move × Minority=1		0.047	0.048	
		(0.097)	(0.096)	
1. Move × 1. Generation				0.226***
				(0.051)
2. Move × 1. Generation				0.083
				(0.060)
3. Move × 1. Generation				0.141
				(0.135)
1. Move × 2. Generation				−0.005
				(0.078)
2. Move × 2. Generation				−0.047
				(0.075)
3. Move × 2. Generation				−0.026
				(0.129)
R^2	0.056	0.057	0.057	0.058
Adj. R^2	0.056	0.056	0.057	0.057
AIC	67185	67166	67153	66880
Number of households	12037	12037	12037	12005
Observations	38385	38385	38385	38268

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cluster robust standard errors in parentheses. Additional controls: Age^2, children living in household, change of household head, duration of residence, year.

households. Approximately 50 per cent of the households with a native German household head moved at least once within our observation period compared to 64 per cent of the minority households. Furthermore, minority households perceive a higher average level of impairment through air pollution. However, in both groups nearly 50 per cent of households experienced at least one improvement in air quality over time. In addition, minority households report on average a 250 EUR lower household income, which indicates that the higher pollution experienced by minority households might be a function of socio-economic status ('racial income-inequality hypothesis').

To draw conclusions about the mechanisms leading to environmental inequality, Table 2 presents the results of the panel regressions. All models are two-way fixed-effects models with cluster robust standard errors. We begin with a discussion of income inequality and then turn to the minority effect.

Model FE 1 includes household income, moving behaviour, and their interaction as explanatory variables. The important construct for testing the effects of selective

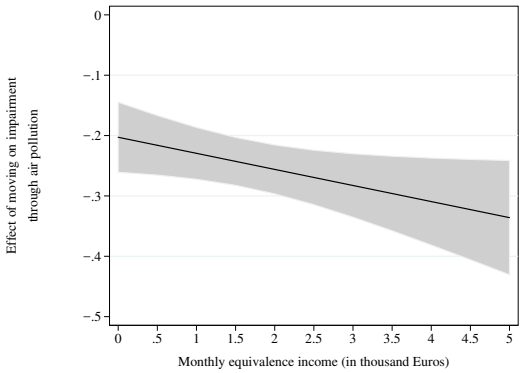

Figure 1. Conditional effect of the first move on the impairment through pollution with 95 per cent confidence interval (FE 2).

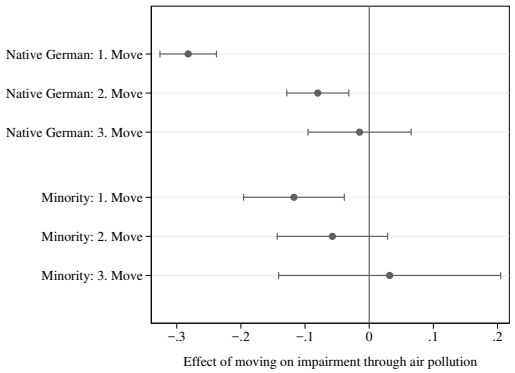

Figure 2. The effect of moving for native German and immigrant minority households on the impairment through pollution with a 95 per cent confidence interval (FE 2)

migration is the interaction of moving behaviour and income which separates the effect of movers and non-movers. In line with our H1, FE 1 shows a significant reduction of the perceived pollution due to income for movers only. This confirms the 'market explanation'. When moving, households experience a higher reduction of perceived air pollution as their income rises. Figure 1 shows how the reduction of pollution due to moving increases with income. In contrast, the effect of income for stationary households is close to zero and not significant: only when moving, households can use their income to reduce their exposure to pollution. Note, however, that the effect is statistically significant but low in magnitude. An increase in income by 1,000 Euro increases the effect of mobility on impairment through air pollution by only 0.03 points (which equals 0.05 standard deviations). This income interaction effect equals three times the presented effect if we interact moving behaviour with the household's average income over time, which would compare the moving returns between 'rich' and 'poor' households (see Supplementary Table SA4).[8] Independent of model choice, our results confirm selective migration as a causal mechanism of environmental inequality.

Turning to the minority effect, model FE 2 includes the main moving effects and an interaction between moving behaviour and minority status. While the interaction terms in combination with the main effects represent the effect of migration for minority households, the main moving effects represent migration returns for native German households. In consonance with H2, we find a significant and negative effect of migration for native German households: the first observed move reduces the perceived impairment through air pollution by nearly 0.28 points on a scale from 1 to 5 (which equals approximately 0.47 within standard deviations). In contrast, minority members experience a much lower reduction in pollution when moving (reduction by approximately 0.12 points or 0.20 within standard deviations). This is a substantial difference and confirms our H2: the improvement due to mobility is more than twice as strong for native German households than for minority households. Figure 2 depicts the results graphically. Even the effect of the second move exceeds the 1 per cent significance level for native German households and points to an average additional improvement due to a second move, while it is non-significant for minority households.

[8] We argue that comparing different income levels within the same household over time is the adequate strategy to model the effect, as it uses within-variance only. The strategy may produce conservative point estimates but is less prone to biases induced by unobservable confounders.

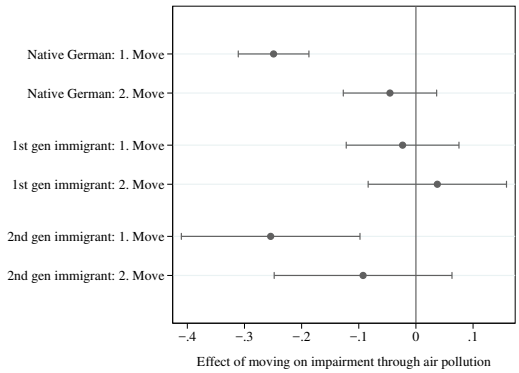

Figure 3. The effect of moving for native German, first-, and second-generation immigrant households on the impairment through pollution with a 95 per cent confidence interval (FE 4, controlling for income).

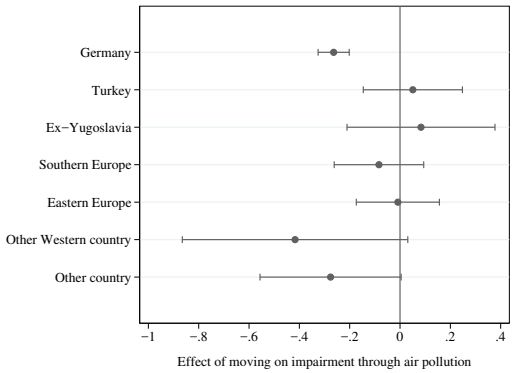

Figure 4. The effect of the first move for native German and first generation immigrant households separated by their country of origin on the impairment through pollution with a 95 per cent confidence interval

These results confirm selective migration as a cause of the disproportionate exposure to air pollution of minority households (H2).

Model FE 3 tests the 'racial income-inequality hypothesis' and includes income as well as minority status with its moving interactions. If the effect of the household's minority status was a result of lower socio-economic status, the minority effect should disappear or diminish under control of income. Still, the difference in reduction of air pollution between native German and minority movers remains nearly unaffected when controlling for income (comparing FE 2 and FE 3). Independent of income, native German households can experience a much higher reduction in air pollution than their minority counterparts do. In contrast to the 'racial income-inequality hypothesis', we do not find any significant effect of household income and only a slight decrease of the minority effect in model FE 3. As in previous research, we observe a persistently lower effect of mobility on the exposure to pollution for minority households, even when controlling for income. Interestingly, the interaction between moving and income fails to reach the 5 per cent significance level in model FE 3, which is in line with the results of Ringquist (2005) who concludes that the minority effect is much more robust than the income effect.

The last model (FE 4) separates the effect of minority status for first- and second-generation immigrants. The results show that the disadvantage of minority households identified in Models FE 2 and FE 3 completely stems from the disadvantage of first-generation immigrants. Figure 3 compares the effect of the first two moves for native Germans, separating first- and second-generation immigrants (under control of income). It turns out that the improvement of the pollution level from moving to a new place of residence experienced by second-generation immigrants is comparable to the improvements experienced by native Germans. First-generation immigrants, in contrast, do not experience any improvement in exposure to pollution when moving. Even under control for income, native Germans, as well as second-generation immigrants, sort into neighbourhoods with lower environmental pollution when moving, while first-generation immigrants face the same exposure to pollution after moving to a new place of residence. Additional analyses of first-generation minority households (Figure 4, see Supplementary Table SA5) reveal that especially households originating from Turkey, Ex-Yugoslavia, and Eastern Europe are disadvantaged compared to native German households ($p \leq 0.05$). Households from those countries are not able

to improve environmental quality due to mobility. Immigrants from wealthy Western countries, such as France, the United Kingdom, or the United States, in contrast, seem to experience the similar average improvement in environmental conditions due to moving as native Germans do, but the estimation of this effect is based on few cases only and statistically not significant.

5. Summary and Conclusion

Environmental inequality has become an important topic of sociological research in the United States. This research has led to several important findings on the differential exposure of minorities to pollutants. Despite this, previous studies have led to inconsistent results regarding the causes of environmental inequality, and empirical studies in Europe are rare. In this article we present the first causal-analytic panel study of environmental inequality in Germany.

To investigate causal mechanisms, this article uses household-level panel data and fixed-effects estimators. We find that income has a significant impact on the level of perceived air pollution for movers, while it has no effect for stationary households: An increase in income leads to a significant reduction of air pollution when the household moves to a new place of residence. This confirms the existence of selective moving processes that shape environmental inequality. However, the effect of income is relatively low in magnitude and sensitive to model specification. When simultaneously including income and nationality, the effect of income loses significance. Regarding minority status, we find a significant improvement in air quality due to migration for native German households. Minority households, in contrast, only experience weak improvements. The disadvantages are especially strong for first-generation immigrants, who do not improve their situation at all when moving. This minority-difference in mobility patterns is robust against model specifications. Thus, selective migration behaviour operates as a causal mechanism, shaping the difference in pollution regarding minority status and, to a lower extent, income. These findings are consistent with previous results on the individual level from the United States (Crowder and Downey, 2010; Pais et al., 2014).

The fact that we find a moderate income-effect but a strong difference between native German and minority households is especially interesting in the German context. As German minorities are far less segregated than minority groups in the United States, we would have expected to observe lower minority differences. However, our data show that first-generation immigrant minorities in Germany are confronted with a high disadvantage when relocating and, thus, experience a higher exposure to pollution. This is true especially for first-generation immigrants from Turkey, former Yugoslavia, and Eastern Europe.

In summary, our analyses confirm selective migration as a causal mechanism of environmental inequality. Nevertheless, this study can only be a first step towards understanding the fine-grained mechanisms triggering selective migration. Our data allow to rule out some mechanisms prominently discussed in the literature: first, we do not find a noteworthy reduction of the minority effect when controlling for income, which indicates that minority disadvantages cannot be explained solely by their relatively low socio-economic status. This contradicts the 'racial income-inequality hypothesis'. Secondly, the disadvantage of immigrants completely vanishes in the second generation, indicating that the disadvantage does not stem from discriminative behaviour triggered by simple ethnic markers like the look or the name of a person. This contra-

dicts the 'racial residential discrimination thesis', but results are not fully conclusive, as discrimination could still occur based on other characteristics like language skills or citizenship. These characteristics are predominantly visible in the first immigrant generation and, thus, would lead to disadvantages in the first but not in the second generation.

At the same time, we cannot rule out that mechanisms other than income or discrimination play a role: first, successful integration of second-generation immigrants could also lead to informal network structures that support the search for high-quality housing. Following this argument, the disadvantage of first-generation immigrants would stem from their ethnic networks and their lack of sufficient ties to the mainstream. Secondly, homogeneity preferences might play an important role in residential choice (Kim et al., 2014), affecting predominantly first-generation immigrants. Thirdly, preferences for environmental quality might differ between Germans/second-generation immigrants on one side and first-generation immigrants on the other. Addressing these potential explanations in further research could produce important insights of the fine-grained mechanism of selective migration, hence bolstering our understanding of the causal mechanisms of environmental inequality.

A shortcoming of the present study is the subjectivity of the pollution measure. Though a strong correlation with noise pollution and proximity to the city centre indicates a connection to traffic-related air pollution, it remains a subjective measure. Thus, its use may be critical for cross-sectional analyses because of differing perceptions of pollution (as criticized by Diekmann and Meyer, 2010). Fixed-effects panel estimators, in contrast, do not rely on the consistency of perception between respondents, which strongly reduces the concerns brought forward against the use of perceived impairment. Nevertheless, further research should validate the results by combining objective and subjective measures of air pollution in a panel study (note that the cross-sectional study by Diekmann and Meyer (2010) found a correlation between objective and subjective pollution data).

Finally, it is important to note that we did not address the question 'which came first?' (Pastor et al., 2001): we did not study facility siting or clean-up behaviour, which was identified as another cause of environmental inequality by previous research, stating that facilities are sited disproportionately close to minorities. Our analysis offers strong evidence for selective migration as a causal mechanism but cannot claim selective migration as the exclusive or the most important mechanism. To complete the picture of causality producing environmental inequality, further research needs to combine micro panel data and longitudinal macro data to analyse selective migration as well as selective siting in one single study. This could also help to explain the fact that macro-level studies were not able to find evidence for selective migration processes, while micro-level studies do.

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Appendix A. Supplements

Table A1. Pooled OLS estimation of perceived impairment through air pollution.

	POLS 1	POLS 2	POLS 3	POLS 4
Monthly equivalence income (in 1,000 Euros)	−0.065***		−0.064***	−0.064***
	(0.008)		(0.008)	(0.008)
Minority		0.073***	0.068***	
		(0.017)	(0.017)	
Minority (1st-generation immigrant)				0.075***
				(0.021)
Minority (2nd-generation immigrant)				0.057*
				(0.027)
Female household	0.062***	0.080***	0.065***	0.066***
	(0.014)	(0.014)	(0.014)	(0.014)
Education[a]				
(Ref: high)				
Other	0.708	0.829	0.722	0.719
	(0.444)	(0.445)	(0.443)	(0.444)
Drop out	0.002	0.026	−0.043	−0.048
	(0.048)	(0.049)	(0.050)	(0.050)
Low	−0.028	0.029	−0.032	−0.033
	(0.019)	(0.017)	(0.019)	(0.019)
Medium	−0.029	0.015	−0.026	−0.026
	(0.019)	(0.018)	(0.019)	(0.019)
Constant	1.719***	1.601***	1.690***	1.695***
	(0.099)	(0.099)	(0.099)	(0.099)
R^2	0.067	0.063	0.069	0.069
Adjusted R^2	0.066	0.062	0.068	0.068
AIC	24842.898	24897.594	24829.038	24826.164
BIC	24971.033	25025.729	24965.715	24971.382
Observations	37886	37886	37886	37881

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Standard errors in parentheses. Additional controls: Age, age^2, children living in household, year.

[a] Categorized Casmin classification: Other (unspecified); Drop out (1a); Low (1b, 1c); Medium (2a, 2b, 2c_gen, 2c_voc), High (3a, 3b).

Table A2. Fixed-effects estimation of additive pollution index (perceived impairment through air pollution and perceived impairment through noise).

	FE 1	FE 2	FE 3	FE 4
Monthly equivalence income (in 1,000 Euros)	−0.001		−0.003	−0.003
	(0.015)		(0.015)	(0.015)
1. Move	−0.421***	−0.573***	−0.521***	−0.525***
	(0.056)	(0.043)	(0.060)	(0.060)
2. Move	−0.090	−0.118*	−0.088	−0.099
	(0.074)	(0.047)	(0.078)	(0.079)
3. Move	0.017	−0.061	−0.022	−0.054
	(0.175)	(0.082)	(0.178)	(0.181)
1. Move × income	−0.044		−0.033	−0.031
	(0.025)		(0.025)	(0.025)
2. Move × income	−0.008		−0.012	−0.009
	(0.036)		(0.036)	(0.037)
3. Move × income	−0.019		−0.017	−0.002
	(0.089)		(0.089)	(0.090)
1. Move × minority		0.372***	0.365***	
		(0.085)	(0.085)	
2. Move × minority		−0.001	−0.007	
		(0.093)	(0.094)	
3. Move × minority		0.170	0.167	
		(0.189)	(0.189)	
1. Move × minority (1st-generation immigrant)				0.482***
				(0.098)
2. Move × minority (1st-generation immigrant)				0.128
				(0.116)
3. Move × minority (1st-generation immigrant)				0.417
				(0.262)
1. Move × minority (2nd-generation immigrant)				0.067
				(0.145)
2. Move × minority (2nd-generation immigrant)				−0.142
				(0.139)
3. Move × minority (2nd-generation immigrant)				−0.039
				(0.255)
R^2	0.052	0.054	0.054	0.055
Adjusted R^2	0.052	0.053	0.053	0.054
AIC	113588.868	113536.082	113536.606	113090.537
Number of households	12037.000	12037.000	12037.000	12005.000
Observations	38371	38371	38371	38254

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cluster robust standard errors in parentheses. Additional controls: Age^2, children living in household, change of household head, duration of residence, year.

Table A3. Fixed-effects ordered-logit (BUC) estimation of perceived impairment through air pollution.

	FE 1	FE 2	FE 3	FE 4
Monthly equivalence income (in 1,000 Euros)	−0.015		−0.020	−0.018
	(0.038)		(0.038)	(0.038)
1. Move	−0.391***	−0.729***	−0.524***	−0.524***
	(0.093)	(0.063)	(0.098)	(0.099)
2. Move	−0.018	−0.171*	−0.046	−0.074
	(0.126)	(0.073)	(0.134)	(0.134)
3. Move	−0.049	0.037	−0.055	−0.064
	(0.219)	(0.118)	(0.224)	(0.226)
1. Move × income	−0.154**		−0.133**	−0.134**
	(0.050)		(0.050)	(0.050)
2. Move × income	−0.052		−0.054	−0.042
	(0.070)		(0.071)	(0.070)
3. Move × income	0.081		0.075	0.076
	(0.115)		(0.115)	(0.115)
1. Move × minority		0.465***	0.434***	
		(0.116)	(0.116)	
2. Move × minority		0.108	0.087	
		(0.134)	(0.134)	
3. Move × minority		0.074	0.075	
		(0.247)	(0.246)	
1. Move × minority (1st-generation immigrant)				0.577***
				(0.135)
2. Move × minority (1st-generation immigrant)				0.280
				(0.158)
3. Move × minority (1st-generation immigrant)				0.282
				(0.337)
1. Move × minority (2nd-generation immigrant)				0.062
				(0.200)
2. Move × minority (2nd-generation immigrant)				−0.121
				(0.210)
3. Move × minority (2nd-generation immigrant)				−0.096
				(0.329)
Pseudo R^2	0.068	0.068	0.069	0.070
AIC	28934.399	28932.364	28905.100	28764.005
Number of households	8053	8053	8053	8026
Observations	27814	27814	27814	27711

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cluster robust standard errors in parentheses. Additional controls: Age^2, children living in household, change of household head, duration of residence, year.

Table A4. Fixed-effects estimation of perceived impairment through air pollution with time-constant average income over time per household.

	FE 1	FE 2	FE 3	FE 4
Monthly equivalence income (in 1,000 Euros)	-0.017^{*}		-0.017^{*}	-0.016^{*}
	(0.008)		(0.008)	(0.008)
1. Move	-0.136^{***}	-0.282^{***}	-0.186^{***}	-0.194^{***}
	(0.040)	(0.022)	(0.041)	(0.042)
2. Move	-0.001	-0.080^{**}	-0.009	-0.018
	(0.049)	(0.025)	(0.051)	(0.051)
3. Move	-0.070	-0.015	-0.081	-0.106
	(0.104)	(0.041)	(0.105)	(0.107)
1. Move × $\overline{\text{income}}$	-0.072^{**}		-0.061^{**}	-0.057^{**}
	(0.022)		(0.022)	(0.022)
2. Move × $\overline{\text{income}}$	-0.046		-0.044	-0.040
	(0.028)		(0.028)	(0.028)
3. Move × $\overline{\text{income}}$	0.043		0.043	0.059
	(0.065)		(0.065)	(0.066)
1. Move × minority		0.165^{***}	0.151^{***}	
		(0.044)	(0.044)	
2. Move × minority		0.023	0.010	
		(0.049)	(0.049)	
3. Move × minority		0.047	0.055	
		(0.097)	(0.097)	
1. Move × minority (1st-generation immigrant)				0.213^{***}
				(0.051)
2. Move × minority (1st-generation immigrant)				0.076
				(0.060)
3. Move × minority (1st-generation immigrant)				0.159
				(0.136)
1. Move × minority (2nd-generation immigrant)				-0.001
				(0.078)
2. Move × minority (2nd-generation immigrant)				-0.050
				(0.075)
3. Move × minority (2nd-generation immigrant)				-0.029
				(0.128)
R^2	0.057	0.057	0.057	0.058
Adjusted R^2	0.056	0.056	0.057	0.058
AIC	67168.037	67165.851	67140.184	66869.202
Humber of households	12037	12037	12037	12005
Observations	38385	38385	38385	38268

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cluster robust standard errors in parentheses. Additional controls: Age^2, children living in household, change of household head, duration of residence, year.

Table A5. Fixed-effects estimation of perceived impairment through air pollution (full models).

	FE 1	FE 2	FE 3	FE 4	FE 5
Monthly equivalence income (in t Euros)	−0.008		−0.009	−0.009	−0.010
	(0.009)		(0.009)	(0.009)	(0.009)
1. Move	−0.203***	−0.282***	−0.247***	−0.249***	−0.254***
	(0.030)	(0.022)	(0.031)	(0.032)	(0.031)
2. Move	−0.034	−0.080**	−0.039	−0.045	−0.050
	(0.039)	(0.025)	(0.042)	(0.042)	(0.041)
3. Move	−0.014	−0.015	−0.023	−0.034	−0.041
	(0.086)	(0.041)	(0.087)	(0.088)	(0.089)
1. Move × income	−0.027*		−0.022	−0.021	−0.017
	(0.013)		(0.013)	(0.013)	(0.013)
2. Move × income	−0.019		−0.020	−0.018	−0.018
	(0.020)		(0.020)	(0.020)	(0.020)
3. Move × income	0.009		0.009	0.014	0.015
	(0.044)		(0.044)	(0.045)	(0.045)
1. Move × minority		0.165***	0.159***		
		(0.044)	(0.044)		
2. Move × minority		0.023	0.015		
		(0.049)	(0.049)		
3. Move × minority		0.047	0.048		
		(0.097)	(0.096)		
1. Move × minority (1st-gen. immigrant)				0.226***	
				(0.051)	
2. Move × minority (1st-gen. immigrant)				0.083	
				(0.060)	
3. Move × minority (1st-gen. immigrant)				0.141	
				(0.135)	
1. Move × minority (2nd-gen. immigrant)				−0.005	
				(0.078)	
2. Move × minority (2nd-gen. immigrant)				−0.047	
				(0.075)	
3. Move × minority (2nd-gen. immigrant)				−0.026	
				(0.129)	
1. Move × Turkey					0.317**
					(0.101)
2. Move × Turkey					0.096
					(0.112)
3. Move × Turkey					0.328
					(0.225)
1. Move × Ex-Yugoslavia					0.349*
					(0.150)
2. Move × Ex-Yugoslavia					−0.163
					(0.154)
3. Move × Ex-Yugoslavia					0.287
					(0.377)
1. Move × Southern Europe					0.180
					(0.092)
2. Move × Southern Europe					0.309**
					(0.113)
3. Move × Southern Europe					−0.005
					(0.232)
1. Move × Eastern Europe					0.251**
					(0.084)
2. Move × Eastern Europe					−0.038
					(0.103)
3. Move × Eastern Europe					0.177
					(0.218)

To be continued.

Table continued

	FE 1	FE 2	FE 3	FE 4	FE 5
1. Move × Other Western country					−0.155
					(0.225)
2. Move × Other Western country					0.116
					(0.282)
3. Move × Other Western country					−0.780
					(0.481)
1. Move × Other country					−0.005
					(0.142)
2. Move × Other country					0.238
					(0.191)
3. Move × Other country					0.038
					(0.409)
Residence < 6 month	−0.138***	−0.136***	−0.138***	−0.140***	−0.141***
	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Change of household headheight	−0.088***	−0.083***	−0.087***	−0.085***	−0.084***
	(0.024)	(0.024)	(0.024)	(0.025)	(0.025)
Age ^{2}	$-7.8e^{-05}$***	$-7.3e^{-05}$***	$-7.7e^{-05}$***	$-8.0e^{-05}$***	$-7.9e^{-05}$***
	$(1.6e^{-05})$	$(1.6e^{-05})$	$(1.6e^{-05})$	$((1.6e^{-05})$	$(1.6e^{-05})$
Children in household	0.053***	0.061***	0.056***	0.061***	0.062***
	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
R^2	0.056	0.057	0.057	0.058	0.059
Adjusted R^2	0.056	0.056	0.057	0.057	0.058
AIC	67185.499	67165.851	67153.243	66880.462	66696.180
Number of households	12037.000	12037.000	12037.000	12005.000	11977.000
Observations	38385	38385	38385	38268	38158

$^{***}p < 0.001$, $^{**}p < 0.01$, $^{*}p < 0.05$. Cluster robust standard errors in parentheses.