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**Article — Published Version**

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Journal of Epidemiology and Community Health

**Provided in Cooperation with:**

WZB Berlin Social Science Center

*Suggested Citation:* Ding, Xuejie; Akimova, Evelina T; Zhao, Bo; Dederichs, Kasimir; Mills, Melinda C (2024) : Prepayment meters strongly associated with multiple types of deprivation and emergency respiratory hospital admissions: an observational, cross-sectional study, Journal of Epidemiology and Community Health, ISSN 1470-2738, BMJ Publishing Group, London, Vol. 78, Iss. 1, pp. 54-60, <https://doi.org/10.1136/jech-2023-220793>

This Version is available at:

<https://hdl.handle.net/10419/318270>

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# Prepayment meters strongly associated with multiple types of deprivation and emergency respiratory hospital admissions: an observational, cross-sectional study

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► Additional supplemental material is published online only. To view, please visit the journal online (<http://dx.doi.org/10.1136/jech-2023-220793>).

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Received 2 May 2023

Accepted 22 September 2023

Published Online First

19 October 2023



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**To cite:** Ding X, Akimova ET, Zhao B, et al. *J Epidemiol Community Health* 2024;**78**:54–60.

## ABSTRACT

**Background** Prepayment meters (PPMs) require energy to be paid in advance. Action groups and media contend that PPMs are concentrated in the most vulnerable groups, prone to run out of credit and experience financial burden. This led to forced installation for those over age 85 being banned in April 2023 and a 'prepayment premium' scrapped in July 2023. Yet, we lack empirical evidence of which groups PPMs are concentrated. This ecological study examines the extent to which PPMs are associated with multiple measures of structural social, economic and health deprivation to establish evidence-based policy.

**Methods** Combining multiple regional data and census estimates at the Lower Layer Super Output Area and the Middle Layer Super Output Area level from England and Wales, we use Spearman's rank correlation, Pearson correlation and multivariate linear regression to empirically establish associations between PPMs and multiple types of deprivation.

**Results** Higher PPM prevalence is strongly associated with: lower income, receipt of employment benefits, ethnic minorities, lower education and higher health deprivation. Higher PPM prevalence is strongly associated with higher income deprivation affecting children, the elderly and social rental properties. PPMs are significantly associated with emergency hospital admissions for respiratory diseases in England, even after controlling for confounders (coefficient=1.81; 95% CI 1.51 to 2.11).

**Conclusions** We found empirical evidence that PPM users are concentrated among the population who already experience multiple disadvantages. Furthermore, PPM concentrated areas are associated with higher emergency hospital admissions for respiratory diseases.

## INTRODUCTION

Prepayment meters (PPMs) require for energy to be paid in advance. Action groups have found that over 3 million people ran out of credit on PPMs in 2022, with more than 94 000 PPMs forcibly installed. British Gas was reported to have sent debt collectors to forcibly instal PPMs in vulnerable households. On 18 April 2023, Ofgem banned forced installation of PPMs for those over 85.<sup>1,2</sup> On 1 July 2023, the government scraped the unfair charge on PPM customers so that PPM households no longer

## WHAT IS ALREADY KNOWN ON THIS TOPIC

- ⇒ Dramatic increases in energy and costs of living have led to an affordability crisis of heating and food for the most vulnerable households in the UK.
- ⇒ Action groups argue that prepayment meters (PPM) usage is prevalent among the most vulnerable groups, which further exacerbates debt and inequalities. However, there is currently a lack of empirically-based scientific and replicable research findings documenting the association between PPMs with vulnerabilities by social, economic, health, age or disability factors.

## WHAT THIS STUDY ADDS

- ⇒ This study moves beyond editorial calls about this problem to provide empirical evidence to demonstrate that PPMs are clearly concentrated among those who already occupy the most vulnerable positions in society, strongly associated with a multitude of economic, social and health structural deprivation indicators.
- ⇒ PPMs are associated with emergency hospital standardised admission ratios for chronic obstructive pulmonary disease in England even after controlling for economic deprivation and demographic factors, with an explanatory power ranging from 3% to 47%.

## HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

- ⇒ Although the current study examines associations and cannot draw definitive causal claims, in addition to increasing debt, PPMs are highly correlated with higher levels of emergency hospital admissions.
- ⇒ Focussing on households with PPMs could serve as a tailored, identifiable, effective and efficient group to target with interventions to alleviate multiple forms of deprivation and emergency hospital admissions for respiratory diseases.

pay more for energy than direct debit customers.<sup>3</sup> Although widely reported, we lack a scientifically grounded analysis (eg, shortage of data, but also a deficiency in rigorous research) of the relationship

of PPMs within vulnerable populations to form evidence-based policy.

Energy and cost of living prices soared in 2021, with a 109% and 138% increase in wholesale gas and electricity prices, respectively.<sup>4</sup> PPMs have been allegedly imposed by landlords or energy suppliers on the poorest, most heavily indebted households.<sup>5</sup> In 2022, 4.3 million UK residents used PPMs, with an estimated half million obliged to switch from direct debit to PPMs by the end of 2022.<sup>6,7</sup> Whereas 20% of all UK households use PPMs, they are concentrated in 33% of low-income households.<sup>8</sup> Prepayment tariffs are also more expensive than direct debit tariffs with UK lower-income households paying approximately £60 more per year in energy costs compared with wealthier counterparts.<sup>9</sup> By the end of 2022, the poorest 10% of families spent 47% of their disposable income on energy costs, while the top 10% contributed 20%. Interruptions in power usage can occur if a supplier disconnects the energy supply or if the customer disconnects due to a failure to recharge the PPM on time. This can result in homes without heat, leading to adverse health impacts, particularly respiratory diseases.<sup>10</sup>

This ecological study examines the density of PPMs by multiple deprivation indicators and geography, using local authority level data from England and Wales. We first examine whether PPM prevalence and fuel poverty is associated with higher regional economic deprivation. Economic deprivation is measured at the area level instead of the individual level, given the fact that we do not have individual-level economic data for England and Wales linked with PPM prevalence data. We then examine whether PPM prevalence is higher in areas with more social housing and private rental properties, indicating that people in these social rental properties are more likely to be PPM users. Finally, we examine the association between PPMs and emergency hospital admissions for respiratory disease, illustrating the potential health consequences of PPMs.

The overall interest of the authors in this study is to provide data-driven empirical evidence on the concentration of PPMs among specific groups and the associated social, economic and health indicators of deprivation. It is important to determine which groups PPMs are concentrated in to inform evidence-based policy decisions and interventions. By identifying the vulnerable populations that are more likely to have PPMs, policy-makers can develop targeted strategies to address the compounded disadvantages faced by these groups.

## METHODS

### Data

#### PPMs at Lower layer Super Output Area (LSOA) level

This study focuses on domestic electricity PPMs in England and Wales. For local PPMs and total meters counts across England and Wales, we used Experimental LSOA Prepayment Electricity Meter Consumption 2017.<sup>11</sup> In England and Wales, 4% (1393 of 32 844) and 1% (28 of 1909) of LSOAs have missing values of PPMs, respectively (online supplemental figure S1). Missing data is concentrated in the least deprived areas due to disclosure control, since LSOAs with fewer than six meters are coded as missing. We cannot include smart meters in prepayment mode, which may underestimate the percentage of PPMs. The data also only includes domestic meters with consumption between 100 and 100 000 kWh.<sup>11</sup>

#### Measures of deprivation and vulnerability at LSOA level

Indices of deprivation (IoD) rank scores for 2019 were at the LSOA level for England<sup>12</sup> and Wales.<sup>13,14</sup> Fuel poverty data 2019

was available only for LSOA in England.<sup>14</sup> Housing tenure type, proportion of multiglazing and house year data are from the Energy Performance Certificate (EPC) 2022.<sup>15</sup> The EPC database was available per postcode, then aggregated to LSOA for England and Wales using lookups between postcode and LSOA from ONS.<sup>16</sup> We removed outliers and duplicates and rounded up figures for frequencies < 10 (online supplemental figure S2). The dataset contains number of properties by: EPC rating, tenure type, construction period and proportion of multiglazed windows at LSOA level. The proportion of ethnic minorities per LSOA was retrieved from the 2011 census.<sup>17</sup> A dataset with information on PPMs, fuel poverty (England), IoD, housing tenure type, proportion of multiglazing, house year and proportion of ethnic minorities was constructed at LSOA level.

#### Emergency admissions rates for chronic obstructive pulmonary disease (COPD) at Middle Layer Super Output Area (MSOA)

Emergency admissions rates for COPD in England were retrieved<sup>18</sup> at the MSOA level. We generated another MSOA level dataset with information on PPMs, fuel poverty, housing tenure type and proportion of ethnic minorities from the above-mentioned LSOA level data using lookups between the LSOA and MSOA level from ONS.<sup>16</sup> Index of Multiple Deprivation (IMD) quintiles at each MSOA level was obtained from 'Maps of local deprivation in England' and mySociety.<sup>19</sup> The final sample for the analysis included 6783 MSOAs with non-missing data.

## Measures

### Percentage PPMs

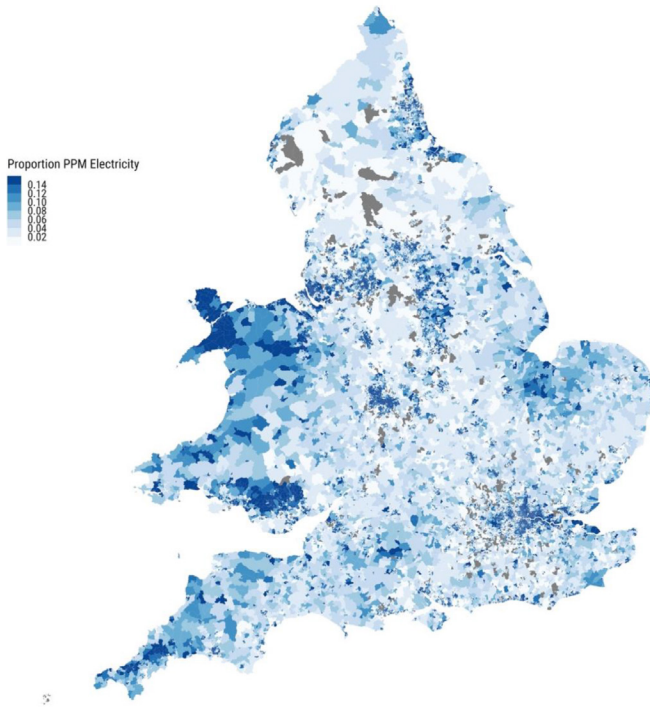
To determine the percentage of PPMs per area, we used the following equation:

$$\% \text{ PPM per area} = \frac{\text{Number of PPMs electricity}}{\text{Total domestic electricity meters}} \quad (1)$$

### Measures of deprivation

The IoD measures relative deprivation by LSOA in England and Wales, with methodology found in the English IoD 2019<sup>20</sup> and Welsh Index of Multiple Deprivation (WIMD) 2019<sup>21</sup> technical reports. The English IoD includes seven domains, with LSOAs ranked from 1 (most deprived) to 32 844 (least deprived), measured as follows:

- ▶ *Income* (22.5%): proportion of income-deprived people within area.
- ▶ *Employment* (22.5%): proportion of working-age population unable to work due to unemployment, sickness or disability, or caring responsibilities.
- ▶ *Education, skills and training* (13.5%): lack of attainment and skills among local population.
- ▶ *Health and disability* (13.5%): risk of premature death and impairment of quality of life due to poor physical or mental health.
- ▶ *Crime* (9.5%): local risk of personal and material victimisation.
- ▶ *Barriers to housing and services* (9.3%): physical and financial accessibility of housing and local services.
- ▶ *Living environment* (9.3%): quality of local environment through two subdomains—quality of housing ('indoors' living environment) and air quality and road traffic accidents ('outdoors' living environment).
- ▶ *IMD*: weights the seven domains with different strength (shown as percentages in brackets) and compiles them into a single score of relative deprivation.<sup>12</sup>



**Figure 1** Subnational (Lower Layer Super Output Area) percentages of prepayment electricity meters. England and Wales. PPM, prepayment meter.

Two indicators are subsets of the broader Income Deprivation Domain,<sup>12</sup> measuring the proportion of the population in an area suffering from low-income deprivation.

- ▶ *Income Deprivation Affecting Children Index*: percentage of children (aged 0–15) who are living in families that are income deprived.
- ▶ *Income Deprivation Affecting Older People Index*: percentage of older individuals (aged 60 or above) who are living in income-deprived conditions.

The Welsh IoD measures relative deprivation for small areas. It identifies areas with the highest concentration of deprivation, ranked from 1 (most deprived) to 1909 (least deprived) and consists of 8 domains as follows:

- ▶ *Income* (23.5%): percentage of people in income deprivation.
- ▶ *Employment* (23.5%): percentage of working-age population in employment deprivation, including those unable to work due to ill-health or unemployed but seeking work.
- ▶ *Health* (14%): conditions of people with General Practitioner (GP)-recorded diagnosis of chronic conditions.
- ▶ *Education* (14%): lack of education, training and skills.
- ▶ *Access to services* (10%): household’s ability to access necessary physical, online services.
- ▶ *Housing* (5%): inadequate housing conditions and availability.
- ▶ *Community safety* (5%): living in a safe community and experiences with crime and fire, perceptions of safety.
- ▶ *Physical environment* (5%): well-being, including air quality, flood risk and green space.
- ▶ *WIMD*: combined for a weighted (shown as percentages in brackets) sum of the domain measures.

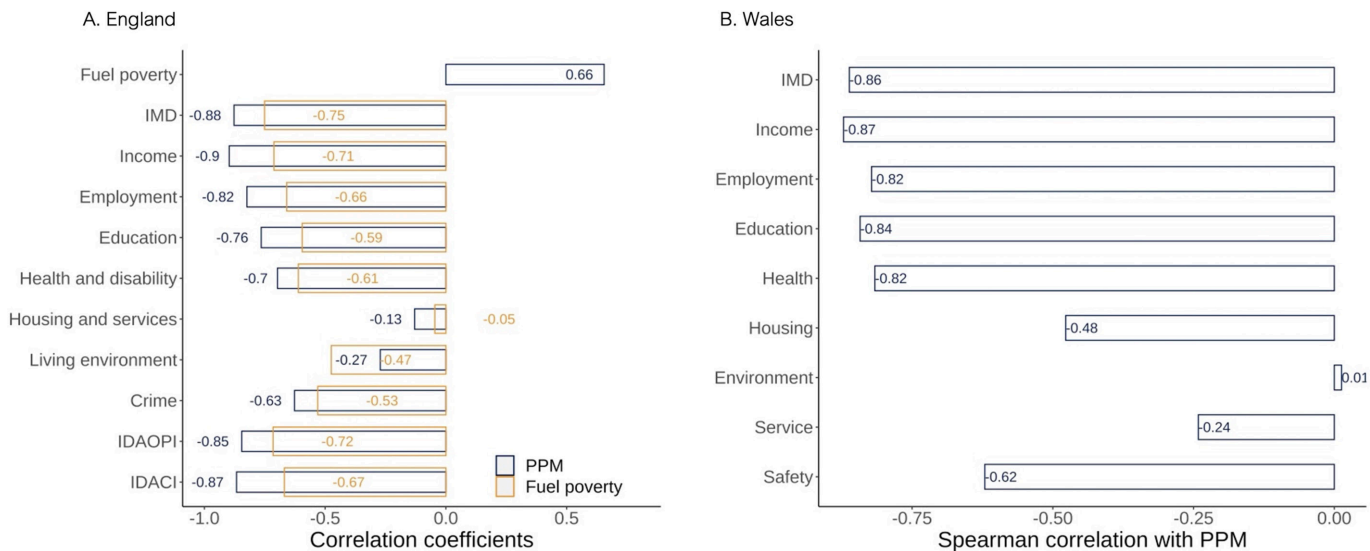
**Fuel poverty, tenure type, quality of housing and ethnicity**

*Fuel poor*: accounts for household income, household energy requirements and fuel prices to determine whether a household is fuel poor.<sup>14</sup>

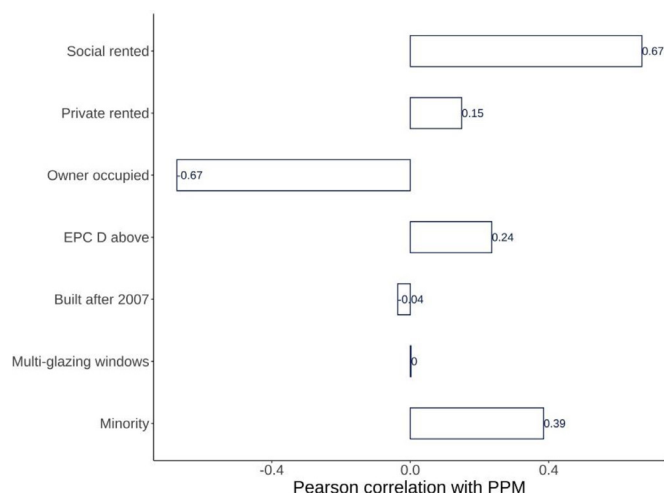
*Tenure type* of housing classified into: rented social housing, rented private housing and owner-occupied housing.

*Quality of housing* is measured by the percentage of properties with: (1) EPC rating of D or higher; (2) built after 2007; and (3) multiglazed windows per LSOA.

*Ethnic minorities* per LSOA retrieved from the 2011 census.<sup>17</sup> The proportion of non-white people (black, Asian, mixed or other ethnic group) is calculated at each LSOA. We include ethnic minorities as an independent variable since they often face unique social, economic and health challenges which may influence their energy usage and ability to afford necessary utilities.<sup>22</sup>



**Figure 2** Correlation between prepayment electricity meters prevalence and multiple deprivation indices. England (A) and Wales (B). The navy bar shows the Spearman correlation coefficients between PPM and each deprivation indices (except for Fuel poverty and PPMs, which is Pearson correlation). The yellow bar shows the Spearman correlation coefficients between fuel poverty and each deprivation index. All coefficients are statistically significant expect for environment in (B). IDACI, Income Deprivation Affecting Children Index; IDAOP, Income Deprivation Affecting Older People Index; IMD, Index of Multiple Deprivation; PPM, prepayment meter.



**Figure 3** Prepayment electricity meters prevalence (Lower Layer Super Output Area) and tenure types, house building year and multiglazing windows in England and Wales. EPC D above, Energy Performance Certificate of D rating or higher; PPM, prepayment meter.

Emergency hospital standard admission ratios (SAR) for COPD. COPD is a chronic inflammatory lung disease that causes obstructed airflow from the lungs. This study included only for England due to data availability and measures how comparatively a person living in that area is to have an emergency admission to hospital compared with the standard population, in this case, the MSOA level in England. SAR is a ratio of the actual number of emergency admissions in MSOA to the number expected if the area had the same age specific admission rates as England, multiplied by 100.<sup>23</sup> An SAR of 100 indicates that the MSOA has an average emergency admission rate with higher than 100 indicating a higher-than-average emergency admission rate and vice versa.

### Analytical strategy

We first map spatial inequality in PPMs by the prevalence of PPMs by LSOA. We then apply a Spearman's rank correlation analysis to measure the strength of the monotonic relationship between prevalence (by %) of PPMs and IoD. Standard parametric correlation analysis (Pearson's *r*) measured the strength of the linear relationship between PPMs and continuous measure of deprivation—that is, fuel poverty, type of tenure, quality of housing.

After checking for a monotonic relationship, ordinary least squares linear regression was used to quantify the association between the prevalence of PPM and emergency hospital admissions rate for England, adjusting for deprivation and controls:

$$\text{EHSAR}_m = \beta \text{PPM}_m + \delta X_i + \epsilon_m \quad (2)$$

Where  $\text{EHSAR}_m$  was the emergency hospital SAR for COPD in England at each MSOA.  $\text{PPM}_m$  was the continuous indicator measuring the prevalence of PPMs per MSOA.  $X_i$  was a vector containing control factors including IMD quintiles, percentage of social rent tenure type, percentage of private rent tenure type and proportion of ethnic minorities. IMD quintile was a categorical variable with the first quintile (most deprived group) being the reference category. Percentage of homeowner tenure type was excluded due to multicollinearity. The analysis includes England only due to unavailable IMD data at the MSOA level and high missingness in tenure types in Wales.

We estimated three models. The first included PPMs as the sole predictor for emergency hospital SAR for COPD, with a bivariate  $R^2$ . Since PPMs are highly associated with deprivation factors and share explanatory power, the bivariate  $R^2$  may be confounded. We therefore ran two additional models: one full model including PPMs and all controls, and another excluding PPMs from the full model. To assess the unique contribution of PPMs, we calculated the partial  $R^2$  following Xie and Zhou.<sup>24</sup>

$$\text{Partial } R^2 = \frac{R^2 - R^2_{\text{PPMs}}}{1 - R^2_{\text{PPMs}}} \quad (3)$$

Where  $R^2$  denotes the  $R^2$  from the full model,  $R^2_{\text{PPMs}}$  denotes the  $R^2$  for the model that includes all variables except PPMs. Hence, the partial  $R^2$  represented the proportion of the remaining variation of emergency hospital SAR for COPD that can be explained by PPMs when all other factors are taken into account.

## RESULTS

### Prevalence and geography of PPMs

England and Wales have, on average, 11% of households using PPMs, with prevalence ranging from as low as 0.46% to as high as 61% across different LSOAs. Wales has a higher prevalence (14%) than England (11%), whereas England has a wider distribution (online supplemental table S1). PPMs are concentrated in major cities such as London, Birmingham, Manchester and also regions in the Northeast, the Wash, Cornwall and Wales (especially North Wales, Cardiff) (figure 1).

### PPMs strongly associated with deprivation, social housing and ethnicity

Correlations between PPM prevalence and IoD are shown in figure 2 (also online supplemental table S2). PPMs are strongly correlated (0.66 (0.65–0.67)) with the fuel poverty index in England. The prevalence of PPMs was more strongly associated with the IoD in every single domain compared with fuel poverty except for the living environment domain, which measures the quality of the indoor and outdoor environment. This is likely attributed to the fact that fuel poverty considers house quality, measured by energy performance rating, and the living environment deprivation domain also measures housing quality. PPM prevalence is strongly associated with multiple types of vulnerability including: lower income (−0.90 (−0.90 to −0.89)), being in receipt of employment benefits (−0.82 (−0.83 to −0.81)), lower education (−0.76 (−0.77 to −0.76)), higher levels of health deprivation (−0.70 (−0.70 to −0.69)), higher income deprivation affecting children (−0.87 (−0.88 to −0.87)) and among older people (−0.85 (−0.86 to −0.85)).

Wales demonstrated the same pattern as England with the exception for housing and environment domains, due to measurement differences. The housing domain in Wales accounts for housing quality, not measured in that domain in England (where it is measured in the living environment domain). The association with housing and PPMs was thus much stronger in Wales (−0.48 (−0.52 to −0.45)) than in England (−0.13 (−0.15 to −0.12)). The physical environment in Wales consists of three weighted domains of: air quality, flood risk and green space, which has a weak association with PPMs (0.01 (−0.13 to 0.06)).

A weak correlation was found between PPMs and barriers to housing and services deprivation (−0.13 (−0.15 to −0.12)). This is surprising since PPMs are thought to be associated with physical and financial accessibility of housing. We therefore conducted a robustness analyses to disentangle this using housing quality data to explore associations between PPMs with tenure

**Table 1** Linear regression models for the relationships between PPMs prevalence and hospital emergency standard admission ratio for COPD in England, n=6783

	Model 1		Model 2		Model 3	
	Coefficient	95% CI	Coefficient	95% CI	Coefficient	95% CI
PPMs	6.55	6.38 to 6.71			1.81	1.51 to 2.11
IMD (ref=Q1)						
Q2			64.30	-67.88 to -60.73	55.41	-59.25 to -51.58
Q3			92.39	-96.37 to -88.41	77.30	-81.97 to -72.62
Q4			111.71	-116.00 to -107.42	92.89	-98.17 to -87.61
Q5			122.86	-127.49 to -118.24	101.26	-107.08 to -95.43
Social rent			1.60	1.47 to 1.72	1.26	1.13 to 1.40
Private rent			0.48	0.35 to 0.61	0.30	0.17 to 0.43
Minority			0.50	-0.57 to -0.42	0.63	-0.71 to -0.56
Intercept	40.92	38.79 to 43.05	157.81	152.03 to 163.58	137.16	130.49 to 143.84
R2	0.47		0.62		0.63	

All coefficients are significant at the <0.001 level.  
COPD, chronic obstructive pulmonary disease; PPMs, prepayment meters.

types, housing quality and proportion of ethnic minorities in England and Wales. PPMs prevalence is strongly associated with social rent (0.67 (0.66 to 0.68)) (figure 3); more likely to be in social housing and less likely in owner occupied properties (-0.67 (-0.68 to -0.66)) and in areas with a higher proportion of ethnic minority groups (0.39 (0.38 to 0.40)).

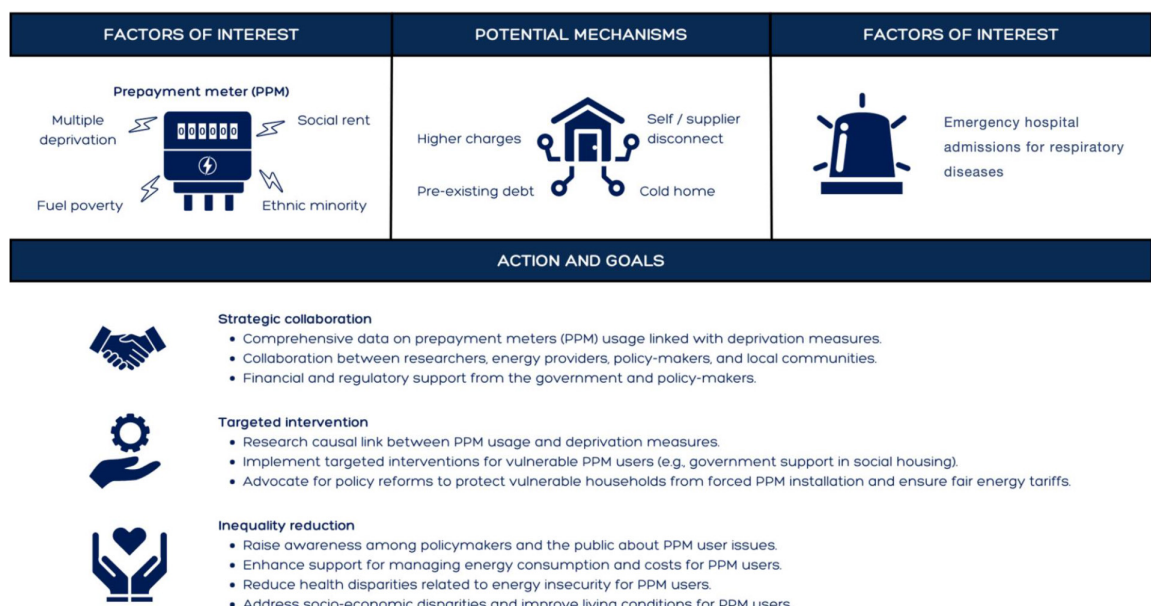
#### PPMs associated with emergency hospital admissions for respiratory diseases

We used ordinary least squares linear regression to quantify the association between PPMs and emergency hospital admission rates for COPD, controlling for IMD, tenure types and proportion of ethnic minority groups. Model 1 in table 1 shows the unadjusted model predicting hospital admission rates for COPD with PPMs as the sole factor. A 1% increase in PPMs is associated with a 6.55 (95% CI 6.38 to 6.71) increase in the SAR. After controlling for confounders, model 3 shows that PPMs are still significantly associated with the emergency hospital SAR for COPD despite that

the effect size diminished to 1.81 (95% CI 1.51 to 2.11). The bivariate  $R^2$  for PPMs on emergency hospital SAR for COPD is 47% (ie,  $R^2$  model 1). The partial  $R^2$  for PPMs on emergency hospital SAR for COPD is 3% (ie, (0.63-0.62)/(1-0.63)). Combining these two  $R^2$  measurements provide us with an interval estimate for assessing the explanatory power of PPMs, with bivariate  $R^2$  being the upper bound and partial  $R^2$  the lower bound, suggesting the relative importance of PPMs to emergency hospital SAR for COPD in England.

#### DISCUSSION

This study demonstrates that PPMs are associated with fuel poverty and multiple types of structural economic, social and health deprivation. We provide a theory of change in figure 4 that encapsulates the process of PPM prevalence and its association with deprivation. PPMs are installed more frequently among individuals experiencing multiple forms of deprivation, including fuel poverty, those residing in social

**Figure 4** Theory of change on prepayment meter prevalence and its association with deprivation.

rented properties and ethnic minority groups. The use of PPMs is associated with adverse effects on health, which may be attributed to several potential mechanisms including: (1) increased fuel costs, which can exacerbate existing financial burdens, (2) operating to compound existing debt, (3) (self-)disconnecting from energy supply due to financial constraints and, (4) (self-disconnection) the subsequent health consequences of living in a cold home.

Our findings clearly establish a significant association between the higher likelihood of PPM installations and multiple forms of deprivation, including those with lower income and education, in receipt of employment benefits, ethnic minorities, social housing rented property occupancy, households with a higher proportion of older people and children living in income-deprived families. This aligns with our initial conjecture that individuals facing economic and social challenges are more predisposed to the adoption of PPMs as a payment method for their energy supply. Unequal concentration across multiple vulnerable groups suggests that the April 2023 policy of focussing on age 85 and older does not capture all exposed groups. The concentration of PPMs in social housing presents a potential avenue for more direct government intervention. However, a detailed evaluation is needed to understand the potential exclusions and compare its efficacy with other intervention methods.

Our data also shows that PPMs are associated with emergency hospital standardised admission ratios for COPD in England, even after controlling for economic deprivation and demographic factors, with an explanatory power ranging from 3% to 47%. However, our data was not able to establish the underlying mechanism between PPMs and health deprivation in our theory of change due to data limitations. It is also important to underline that our research establishes an association, not causation. We are not able to definitively determine whether PPM use causes higher hospital admissions, but rather that a relationship exists. We also note limitations of our study. We examine only England and Wales, excluding smart meters with prepayment mode and as noted, establish correlations between measures and not causation. We call for the release of PPM data in Scotland and Northern Ireland and to include payment methods in social surveys for more preventative, evidence-based energy and public health interventions.

**Correction notice** This article has been corrected since it first published. The open access licence type has been updated to CC BY.

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**Acknowledgements** We thank B. Smith for assistance in enhancing the visual appeal of Figure 4 and for conducting proofreading. We thank T. Pepper for contribution in the development of this publication, along with the two reviewers for their valuable feedback.

**Contributors** Conceptualisation: all authors. Original draft preparation: XD and MCM. Main analysis: XD and MCM. Additional data preparation and analysis: BZ, ETA and KD. Writing, review and editing: MCM. All authors provided substantial critical input to improve the manuscript and all authors approved the final draft. XD and MCM are responsible for the overall content as guarantors.

**Funding** Funding was provided by the ERC (835069), ESRC Connecting Generations (ES/V0141988/1); Leverhulme Trust (Grant RC-2018-003) for the Leverhulme Centre for Demographic Science.

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**Competing interests** None declared.

**Patient consent for publication** Not applicable.

**Ethics approval** In the present ecological study, ethical approval was not applicable as the research exclusively uses publicly available, aggregate-level population data from the UK, with no individual or personal data involved.

**Provenance and peer review** Not commissioned; externally peer reviewed.

**Data availability statement** Data are available upon reasonable request.

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# Correction: *Prepayment meters strongly associated with multiple types of deprivation and emergency respiratory hospital admissions: an observational, cross-sectional study*

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Ding X, Akimova ET, Zhao B, *et al.* Prepayment meters strongly associated with multiple types of deprivation and emergency respiratory hospital admissions: an observational, cross-sectional study. *J Epidemiol Community Health* 2024;**78**:54-60. doi: 10.1136/jech-2023-220793



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*J Epidemiol Community Health* 2024;**78**:271. doi:10.1136/jech-2023-220793corr1

