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ABSTRACT
Drawing on the literature on public service co-production, we examine the individual-level and local government-level factors associated with pro-environmental behaviours. Statistical analysis suggests that individuals that have high levels of self-efficacy, are more civically engaged or are carers, are more likely to 'co-produce' environmental outcomes. In addition, women, rural-dwellers, university graduates and middle-aged individuals exhibit more pro-environmental behaviours. Further analysis suggests that environmental co-production is more prevalent in areas with a high degree of compatibility between local public services and citizens, but worse recycling services and less overall investment in environmental services.

Introduction

Citizen involvement in the production of public services is generating growing interest among public management scholars and policy makers (Brandsen, Steen, and Verschuere 2018; OECD, 2011; Osborne, Radnor, and Strokosch 2016). Defined as 'direct and active contributions' from citizens to the work of public organizations (Brandsen and Honingh 2016), co-production has the potential to help governments address the societal challenges that they now confront (Bates 2012), such as climate change (Bremer and Meisch 2017) and homelessness (Brown et al. 2012). Despite an explosion of scholarship on citizen involvement in delivering public services (Voorberg, Bekkers, and Tummers 2015), surprisingly little research systematically investigates the influence of individual and organizational factors on co-production.

To date, large-scale quantitative studies investigating the determinants of co-production have largely focused on individual-level correlates of citizens' engagement with public services (e.g. Alford and Yates 2016; Bovaird et al. 2015). While this research has contributed greatly to our understanding of the enablers and barriers to co-production, empirical research incorporating a wider frame of reference is needed to grasp the full range of variables that shape citizens' contributions to public service outcomes (Bovaird and Loeffler 2012). In particular, theories of public service co-production point toward the importance of organizational-level factors that facilitate or discourage citizens' engagement with public

services (Voorberg, Bekkers, and Tummers 2015). Building on those theories, we simultaneously analyse individual-level and local government-level factors that influence citizens' pro-environment behaviours in Wales – one of the four constituent nations of the United Kingdom.

Theories of public service co-production indicate that citizens' attitudes and demographic characteristics have a bearing on co-productive behaviours and activities, along with a host of different institutional and political factors that shape opportunities for engagement with public services (Voorberg, Bekkers, and Tummers 2015).

Regarding individual-level attributes, studies have found that solidarity incentives, along with intrinsic motivations and rewards, including civic engagement, self-perceived sense of efficacy, or being a carer for others, are associated with co-production (Alford 2002, 2009; Wise, Paton, and Gegenhuber 2012). Additionally, individual traits such as education, gender, age, and location of residence, have commonly been considered in the related literature as potential predictors of co-production behaviours (see, e.g., Alford and Yates 2016; Bovaird et al. 2016; Egerton 2002; Parrado et al. 2013). As for organizational factors, citizens served by local governments with stronger participatory structures and attitudes, but poorer quality services, may be motivated to engage more with public services (Needham 2008). Each of these factors seems especially likely to influence pro-environmental behaviour, which is characterised by a concern to benefit society and humanity (Berenguer, Corraliza, and Martín 2005).

To understand the relative salience of individual and organizational influences on citizens' co-production, we analyse the pro-environmental behaviours of a sample of citizens in Wales. Environmental sustainability is seen as perhaps the paradigmatic societal challenge requiring citizens' co-productive efforts (Bremer and Meisch 2017), and citizen involvement in the implementation of environmental policies is now a key component of the European Union's 7th Environmental Action Programme (European Union 2014). These policies have been especially influential in Wales, where a commitment to sustainable development has been legislated for via the Well-being of Future Generations (Wales) Act 2015. Indeed, according to some estimates, municipal and household recycling rates in Wales are among the very best in the world (Eunomia 2017). Evidence on the determinants of Welsh citizens' pro-environmental behaviour can therefore cast valuable light on the dynamics of co-production more generally.

Drawing on a large dataset from a national survey of nearly 5,000 citizens, we employ Bayesian multi-level modelling to examine pro-environmental behaviours, such as recycling, volunteering for environmental groups and 'green' consumerism. Multi-level research designs are especially appropriate for understanding individual behaviour since they can estimate the effects on individuals of being nested within higher level units of analysis, such as organizations, local areas or, even, countries (Bryan and Jenkins 2016). For the individual-level of our analysis, we draw upon survey questions measuring three personal attitudes thought to be key to co-production: self-efficacy, civic engagement, and being a carer, along with information on demographic characteristics, such as gender, age, education and urban residence. For the upper level of analysis, we focus on local government-level factors likely to shape citizens' engagement with public services: institutional structures for co-production; local environmental service expenditure and performance; and left-wing political control.

Our analysis suggests that individuals with high levels of self-efficacy, greater involvement in formal groups, carers, and rural-dwellers, women, university graduates or middle-aged, are more likely to 'co-produce' environmental outcomes. At the local

government level, structures for co-production are associated with more pro-environmental behaviours, as are worse quality recycling services and lower expenditure on environmental services in general. However, residents in more risk-averse 'producer-ist' local governments exhibit fewer such behaviours. These results underline the value of multi-level analysis for understanding the dynamics of co-production.

Why do citizens engage in the co-production of public services?

High quality public services provide the essential backbone infrastructure for economic and social wellbeing from which citizens, organizations and firms benefit. In recent years, discussions about the sustainability of public services have gained salience considerably (Homsy 2018), especially in the context of post-crisis austerity policies implemented by many governments in the European Union/West (Burns, Clifton, and Quaglia 2018). These debates have also reflected multiple structural transformations in society, such as demographic changes (Wolf and Amirkhanyan 2010) and technological revolutions (Gil-Garcia, Dawes, and Pardo forthcoming), as well as the rise of 'wicked issues' requiring co-ordinated government action, such as climate change (Pollitt 2015). In response, new ideas about how to invigorate public services by promoting social innovation have emerged (see, e.g., Osborne 2010; Osborne, Radnor, and Nasi 2013). Innovation is a crucial aspect in the quest to adapt public services to better meet the needs of citizens and to obtain value for money in service provision (Osborne 2010). Within this setting, co-production is becoming one of the cornerstones of public service innovation, as a means for improving public service delivery and enhancing the role of public services in achieving societal ends and democratic values (Osborne, Radnor, and Strokosch 2016; Pestoff 2014).

Co-production, however, is an umbrella term covering many different approaches to citizens' involvement in public service delivery (Verschuere, Brandsen, and Pestoff 2012; Voorberg et al. 2018). Indeed, the co-production literature draws on varying, and sometimes contradictory, definitions of what is (and what is not) co-production (Brandsen and Honingh 2016). From early definitions of co-production, based on the work of Ostrom and Ostrom (1977), such as Parks et al. (1981), to very recent works, such as Brandsen and Honingh (2016, 2018) or Nabatchi, Sancino, and Sicilia (2017), a considerable body of scholarship deals with the concept of co-production (see, e.g., Bovaird 2007; Brudney and England 1983; Brandsen and Pestoff 2006; Brandsen and Honingh 2016; Nabatchi, Sancino, and Sicilia 2017; Ostrom 1996; Pestoff 2006, among others). To help frame our study, we draw on one of the most recent definitions of co-production, and understand co-production of public service outcomes, in a broad sense, as a relationship between citizens and public sector organizations that 'requires a direct and active contribution from these citizens to the work of the organization' (Brandsen and Honingh 2016, 431). The domain of our study, i.e. environmental co-production, constitutes an example of what Brandsen and Honingh (2016) define as *co-production in the implementation of core services*. Achieving better environmental outcomes is one of the core responsibilities of local governments in Wales (see, http://law.gov.wales/splash?orig=/constitution-government/government-in-wales). Moreover, the first goal of the Welsh Government's Well-being of Future Generations Act 2015 is to create: 'an innovative, productive and low carbon society which recognises the limits of the global

environment and therefore uses resources efficiently and proportionately (including acting on climate change)' (http://www.legislation.gov.uk/anaw/2015/2/section/4/enacted).

Over the last two decades, understanding of the conditions under which co-production occurs, both from the citizens' and organizational perspectives, has been the object of considerable research efforts (e.g., Alford and Yates 2016; Bifulco and Ladd 2006; Bovaird and Loeffler 2012; Bovaird et al. 2015; Parrado et al. 2013; Voorberg et al. 2017, among others). Research on factors that influence public service co-production has grown in sophistication in recent years: for example, Uzochukwu and Thomas (2018) seek to determine how individual, institutional and political factors shape co-production at different stages (co-planning, co-delivery, co-monitoring) as well as at various levels (individual, group and collective behaviour). Despite the growing sophistication of research aiming to explain factors which influence citizens to co-produce, no research, to the best of our knowledge, quantitatively analyses the combined influence of individual, organizational and contextual factors on citizens' co-production. Although there is an increasing number of studies using quantitative and even experimental approaches (see, e.g., Jakobsen 2012; Voorberg et al. 2018), a substantial strand of the co-production literature has focused on case studies using qualitative data (Brandsen, Steen, and Verschuere 2018). Most of the limited quantitative research exploring citizens' co-production behaviour and attitudes has generally tested the statistical significance and correlates of individual characteristics as part of single-level multivariate statistical models (see Alford and Yates 2016; Bovaird et al. 2015, 2016; Parrado et al. 2013). The main contribution of this study resides, therefore, in the quantification of the relative influence of different levels on citizens' co-production behaviour. In what follows, we briefly explore individual and organizational/contextual factors that may affect citizens' co-production of public service outcomes.

Individual factors influencing citizens' co-production

A growing body of empirical literature examines the determinants of citizens' co-production. Most of these studies identify specific individual characteristics that may influence citizens' co-production behaviour. First, individual attitudes and motivations seem likely to explain co-production levels. A number of scholars have usefully distinguished between material incentives (money, vouchers, etc.), solidarity incentives (belonging to a group) and intangible incentives, including intrinsic rewards or satisfaction with morally good action (Alford 2002, 2009; Sharp 1984; Van Eijk and Steen 2014, 2016).

Beyond material incentives, the desire to belong to a group may result in a sense of satisfaction associated with solidarity incentives such as serving the interest of a community of people (Perry and Hondghem, 2008), or in a broader sense, contributing to the common well-being (Clohesy 2000). Regarding intrinsic rewards, a self-perceived sense of efficacy or, in other words, the notion of *self-efficacy*, seems to be one of the most relevant factors influencing citizens' engagement in co-production (Parrado et al. 2013; Bovaird et al. 2015). It has been argued that citizens' self-efficacy, defined as 'the extent to which they [citizens] feel they can make a difference by influencing the service' (Alford and Yates 2016, 162), constitutes a powerful intrinsic motivator favouring co-production behaviour, since this factor reflects both willingness and ability to have an impact on

public service outcomes (Parrado et al. 2013; Alford and Yates 2016). Though highly complex in psychological terms, one commonly cited expression of intrinsic rewards would be captured by an individual who cares for someone else in the community, and who thereby gains a sense of satisfaction from helping people in need (Batson and Powell 2003).

Besides these incentives, the related literature has identified a number of socio-demographic factors, such as gender, age, education, and the urban/rural divide, that are likely to influence co-production behaviour (see, e.g. Parrado et al., 2013; Bovaird et al. 2015). More specifically, empirical evidence suggests that women are more likely to volunteer than men (Christensen and Lægreid 2005), and express a stronger preference for the environment (Zelezny, Chua, and Aldrich 2000). In addition, the empirical literature on co-production has found that women are associated with more intense individual co-production (Bovaird et al. 2015), including pro-environmental activities (Parrado et al. 2013). Age seems to be another important predictor of co-production; in particular, previous research suggests that the elderly are more likely to engage in civic activities (Putnam 2001) and individual co-production (Parrado et al. 2013; Bovaird et al. 2015). Bovaird et al. (2016) found age to be positively associated with pro-environmental co-production in some, but not all, of the countries in their study. Indeed, the effect of age may be non-linear, since middle-agers appear to be the most proactive when volunteering (Wilson 2012). Alford and Yates (2016) found that some environmental co-production activities were more likely to be done by people in particular age groups (for example, younger people used more public transport whilst age was irrelevant for a 'simple' activity such as recycling). Hence, the influence of age on co-production behaviour is complex.

Education has also been suggested as an important predictor of citizens' participation (Egerton 2002), though most quantitative public administration studies have found that education makes little (or no) difference to co-production levels (Alford and Yates 2016; Parrado et al. 2013). Nevertheless, previous research by sociologists and psychologists suggest that well-educated people are more aware of and concerned about environmental issues (see, e.g., Marquart-Pyatt 2012; Ostman and Parker 1987), which may lead them to actively collaborate in protecting the environment. Hence, we expect that education will be positively correlated with environmental co-production behaviour. Finally, it has been found that living in an urban location may be negatively correlated to the willingness to co-produce, particularly as regards environmental issues (Parrado et al. 2013). This is consistent with some recent studies by environmentalists, which suggest that rural residents place a higher priority on the environment and report higher participation in pro-environmental activities (see, e.g., Berenguer, Corraliza, and Martín 2005; Huddart-Kennedy et al. 2009).

The multilevel nature of co-production

Research in public policy and public administration is increasingly taking into account the multilevel nature of governance or, in other words, the fact that outcomes and processes in public organizations may be the result of individual, organizational, and contextual characteristics operating at different levels (Miller and Moulton 2013, 555). Hence, it is conceivable that a further set of factors that might affect citizens' co-production can be found in the organizational setting.

Voorberg, Bekkers, and Tummers (2015), in a recent systematic review of the co-production literature, identify three key organizational factors that might explain/influence co-production: (i) compatibility of public organizations with citizens' participation, (ii) attitude of public officials towards citizens' participation and, (iii) administrative culture. Paraphrasing Voorberg et al.'s words (1343), compatibility refers to the presence of organizational structures favouring citizens' participation. For example, the presence of community organizations, such as not-for-profit and voluntary organizations, might expose citizens to a wide range of ideas and experiences, which may lead to the development of shared values about public life and collaboration through interaction in horizontal networks (Andrews and Brewer 2010, 578).

Second, attitudes of public officials refer to the willingness of politicians and public servants to collaborate with citizens, which has also been considered a potential predictor of co-production. For example, Coursey, Yang, and Pandey (2012) argue that citizens' participation requires public managers who 'truly value' that participation and, therefore, engage with citizens 'actively and creatively' (578). In this line, public officials willing to engage with citizens would put more effort into providing tools and incentives for citizens' participation (Bryer 2007; Handley and Howell-Moroney 2010). The third organizational factor that might influence co-production refers to the administrative culture of public organizations. Differences in governance traditions may explain variations in co-production behaviour; for instance, inclusive administrative cultures of sharing with non-governmental stakeholders, such as civil society or private actors, may cultivate collaborative structures favouring public services co-production (Voorberg et al. 2017). On the other hand, risk averse, conservative (with a small 'c') administrative traditions that consider citizens as mainly service recipients instead of partners might result in a lack of collaborative structures to encourage participation (Maiello et al. 2013; Voorberg, Bekkers, and Tummers 2015). For example, left-wing controlled governments that support trade unionism and favour in-house public service provision are sometimes assumed to exhibit a 'producerist' attitude that professionals should be trusted to just get on with their job (Geddes 2001; Laffin 2008).

A further organizational factor that might help to explain co-production behaviour is the quantity and quality of public services provided by governments. In this sense, citizens may engage more in co-production activities if they feel that the quantity and/or quality of services provided by government is poor (Alford and Yates 2016). However, it has also been argued that poor government performance (in terms of public service delivery) might undermine citizens' trust in government (Van Ryzin 2007) and, consequently, their willingness to co-produce (Alford and Yates 2016). Hence, the effect of government performance on citizens' co-production may run in both directions.

Data and methods

To explore the factors that may affect citizens' behaviour towards co-production of environmental services, we gathered individual level data from the 2016–2017 National Survey for Wales (NSW), which was conducted by the Welsh Government. The 2016–2017 NSW involved/surveyed over 10,000 people across all 22 Welsh Local Governments (LGs). This large-N survey provides evidence on people's views about different topics such as housing, health, environment, sports

and recreation, democracy and government, among others. The survey results are intended to inform and shape policy decision-making by public organizations in Wales (Aumeyr et al. 2017).[1] The 2016–2017 NSW replaced the Welsh Outdoor Recreation Survey as a source of information on attitudes towards the environment. Informants answering questions related to environmental actions consisted of a survey subsample of 5,266 people. After cleaning the data, our dataset includes 4,957 individual observations across 22 LGs.

Dependent variable

The dependent variable, *environmental co-production*, is a count of the pro-environmental activities undertaken by NSW respondents, which serves as a proxy for environmental co-production behaviour. These activities/behaviours are: (1) recycling, (2) switching to a green energy supplier, (3) buying appliances which are more energy efficient, (4) reducing the amount of energy used at home, (5) purchasing eco-friendly products, (6) gardening for wildlife (7) contacting the local MP (Member of Parliament) or AM (Assembly Member) about environmental issues, (8) signing a petition about climate change or conservation, (9) actively volunteering to help protect the environment and, (10) being a member of an environmental or climate change group. The rationale behind the selection of these activities is to provide a reasonable proxy measure of policy relevant co-productive behaviours. In particular, the behaviours included in our environmental co-production measure are at the core of the Welsh 2006 Environmental Strategy, which put the focus on environmental preservation and mitigating climate change through, among other strategies, sustainable waste management; use of renewal energy sources; increasing energy efficiency and resource efficiency; promoting green (or eco-friendly) products and services; and conservation of landscape, natural beauty, and wildlife.[2]

To construct our environmental co-production indicator, we sum each activity/behaviour coded 1 = respondent undertook the activity, 0 = otherwise, resulting in a co-production index bounded between 0 and 10. This additive approach to constructing co-production indicators has been used in nearly all recent studies attempting to analyse factors influencing co-production behaviour using survey data (see, Parrado et al. 2013; Bovaird et al. 2015).

It is important to sound a note of caution with respect to our co-production measure. Specifically, some of the pro-environmental behaviours included in the co-production index might reflect diverse interests and motivations; a clear example would be reducing the amount of energy at home, which could be motivated by pro-environmental motivations but also by financial constraints, among other potential reasons. Therefore, we cannot entirely discard the possibility that our indicator captures motivations beyond co-productive behaviours, which should be taken into account when interpreting the results. Nonetheless, despite this caveat, we believe that our co-production index provides a reasonable proxy measure of, in particular, policy relevant co-production behaviours as discussed above.

In addition, it should be acknowledged that our aggregated co-production indicator includes both individual-based activities along with group-based activities. This could be problematic since factors influencing individual-based activities and group-based activities might differ (see, Bovaird et al. 2015, 2016), hence

estimating together both types of activities may bias our results. For this reason, we complement our analysis by constructing a co-production index measuring only individual-based activities (i.e., activities 1–8). Our results remain unchanged (see Table A2 and Figures A2 and A3 of the Appendix). Additionally, we construct a third co-production index measuring only group-based activities (activities 9 and 10), which yielded very similar results (available on request).[3] However, it seems that citizens' co-production is more likely to occur when the activities can be carried out individually, since only 263 out of 4957 respondents stated that they participated in group-based activities. Hence, this relatively low number of participants in pro-environmental group-based activities prevent us from drawing strong conclusions about potential correlates of group-based co-production on this occasion.

Individual level explanatory variables

At the individual level, we include three independent variables as proxies for the personal motivations that may influence citizens' co-production behaviour as described in the second section. First, to evaluate the intrinsic motivation related to satisfaction as a consequence of helping people to co-produce we use a dummy variable which takes a value of 1 if the respondent is a carer for other people, i.e., if they look after, or give any help or support to family members, friends, neighbours or others. It has been argued that one of the principal motivational bases of informal care is satisfaction from doing a 'morally good' action (e.g., Abrams and Bulmer 1985), hence this variable, though contestable as are all proxy measures, should account reasonably well for people's intrinsic motivations.

Second, we measure *self-efficacy* using a survey question assessing citizens' perceptions of their influence on local policy decisions. Informants were invited to indicate on a 5-point Likert scale from 1 (strongly agree) to 5 (strongly disagree) the extent to which they were able to influence decisions affecting their local area. To facilitate interpretation of the results we reversed the scale, so that a score of 5 stands for 'strongly agree', whereas a score of 1 reads as 'strongly disagree'. This proxy is similar to those measures of self-efficacy used in previous co-production research (see, Parrado et al. 2013; Bovaird et al. 2015), and is closely related to the concept of internal political efficacy from the political science literature (Balch 1974; Madsen 1987). The prediction is that a higher degree of perceived self-efficacy (or internal efficacy) would be associated with higher levels of citizen participation and civic engagement (Finkel 1985; Pinkleton and Austin 2001), hence associated with a higher number of environmental co-production behaviours.

Third, we evaluate the potential influence of solidarity incentives such as serving a community of people by means of a civic engagement indicator. Engagement is measured here as the degree of citizens' involvement in formal groups or, in other words, citizens' propensity to become members of formal groups or organizations, other than environmental groups. More specifically, our civic engagement indicator is a count of the number of formal groups to which respondents stated they belong (i.e., school group, neighbourhood watch, tenants group, religious groups, sports clubs, etc).

In addition to gauging the influence of being a carer, self-efficacy, and civic engagement on environmental co-production behaviour, we include in our models a number of demographic factors that, as discussed, might affect citizens' co-

production. First, we account for the respondent's gender by including a dummy variable which takes the value of 1 if the informant is a woman. Second, we include a continuous covariate measuring the respondent's age. Education level is measured through a dummy variable taking values of 1 if respondents hold a diploma, first degree, higher degree or equivalent and 0 otherwise. Finally, we include a dichotomous variable coded 1 for those respondents residing in urban areas and 0 for those living in rural areas.

Local government level explanatory variables

In addition to these indicators of individual characteristics, we include measures capturing contextual and organizational factors that might influence co-production behaviour at the local government level. Specifically, we include in our models five variables that proxy for: the existence of organizational structures favouring citizens' participation; the willingness of public officials to engage with citizens; the administrative culture of local governments; and, the quantity and quality of the environmental services that they provide.

First, to proxy for the presence of organizational structures which may foster citizens' participation or, in other words, the degree of organizational *compatibility* regarding co-production, we create a variable (*compatibility*) defined as the logarithm of the number of Communities First partnership members by LG. The Communities First was a community program launched in 2001 by the Welsh Government to help improve local communities and address poverty issues. In each LG, partnerships include representatives (members) from the community, statutory, voluntary and business sectors. Given that the program was addressed to the most deprived neighbourhoods in Wales, deprivation levels and the number of Lower Super Output Areas (LSOA) within each LG may influence the number of partnership members, hence biasing our indicator. To overcome this potential problem, we weighted the indicator using the Welsh Index of Multiple Deprivation and the number of LSOAs in each LG. More specifically our compatibility indicator is computed as follows: $compatibility_i = \log\left[nCF_i * (1 - deprivation_i) * \left(1 - \frac{nLSOAs_i}{Total\ n\ LSOAs}\right)\right]$, where nCF_i refers to the number of partners in LG*i*, *deprivation_i* refers to the percentage of LSOAs in LG *i* among the top 50% most deprived in Wales, and $nLSOA_i$ refers to the number of LSOAs in LG *i*. Information on the number of Communities First partnership members was drawn from the annual monitoring reports that partnerships were required to produce from April 2011 to September 2012. Deprivation data and the number of LSOAs were retrieved from Stats Wales (https://statswales.gov.wales).

Second, we measure the willingness (or reluctance) of public officials to engage with citizens via an aggregated indicator calculated by the Welsh Government using data from the 2014–2015 NSW. More specifically, our proxy measure, labelled as *attitude*, consists of the percentage of informants that strongly agree that their locally elected political representative works closely with the community. We use already aggregated data from 2014–15 instead of creating a similar measure using the 2016–2017 NSW to avoid a potential source of common method bias.

Third, to test the influence on co-production of the administrative culture of public sector organizations, we include in our model a dichotomous variable which takes a value of 1 if the Labour Party controlled the local government after the 2013

Welsh local elections, and 0 otherwise. The prediction is that Labour-controlled governments in Wales might have a risk-averse and conservative 'producerist' culture, which is more focused on professional 'control' rather than citizen involvement and empowerment (Marsh 2008, 259). Such a culture has arguably been evident at all levels of Labour-led government in post-devolution Wales (Reynolds 2008).

To proxy for the quantity and quality of public services provided by the local government we include the following measures. As a first proxy measure for the quantity of environmental services provided by each LG, we include the logarithm of the *per capita* spending on environmental services. Financial resources expended on public services have been commonly regarded in the public administration literature as an important predictor of public service performance (see, e.g., Andrews et al. 2008a). The second proxy accounting for the quality of environmental services is an aggregate indicator of citizens' *satisfaction* with the recycling collection service provided by the LG. More specifically, our measure consists of the percentage of local residents who express they are very satisfied with such services. While we acknowledge that this measure is imperfect, we believe that in our research setting there are sound empirical reasons for regarding it as a plausible proxy for the overall quality of environmental services. While Welsh local governments' environmental services cover a wide range of waste management and environmental protection activities, the collection, processing and promotion of recycling accounts for the largest proportion of money that is spent in this service area – see https://stats wales.gov.wales/Catalogue/Local-Government/Finance/Revenue/Budgets/budgetedre venueexpenditure-by-servicedetail. It is also the aspect of environmental services provision with which nearly all citizens are familiar.

In line with our measure for public officials' *attitude*, we draw on an aggregated indicator provided by the Welsh Government using data from the 2014–2015 NSW. Data sources for all the variables included in our analysis are reported in Table 1, along with descriptive statistics.

Methodology

In order to investigate the individual, contextual and organizational factors influencing environmental co-production behaviour, we employ Bayesian multilevel modelling techniques. Multilevel models, also known as hierarchical models, are especially appealing for our analysis since they can estimate effects both at the individual and at the local government level where individuals reside. Further, our dependent variable, i.e. the number of co-production behaviours, is a count variable. When analysing count data, simple linear regression methods may result in inconsistent, inefficient and biased estimates due to the discrete and nonnegative nature of count variables (Long 1997; Cameron and Trivedi 1998). These properties of count data suggest that, in our case, a multilevel Poisson model might be helpful to account for the count nature of the dependent variable (see, e.g., Gelman and Hill 2007).

To fit such Poisson multilevel models, we propose in this paper the use of Bayesian methods. Although there are a number of efficient Maximum Likelihood (ML)-based estimation techniques to fit multilevel models, Bayesian methods using Markov Chain Monte Carlo (MCMC) techniques have been found to perform better than ML when the number of level-2 units (Welsh LGs in our case) is relatively small (Bryan and Jenkins 2016). Hence, we propose to use a Bayesian approach based on Metropolis-

Table 1. Descriptive statistics and data sources.

	Source	Mean	Std. Dev.	Min	Max
Dependent variable					
Co-production index	A	2.64	1.48	0	10
Individual level explanatory variables					
Carer	A	0.32	0.47	0	1
Self-efficacy	A	2.35	1.13	1	5
Civic Engagement	A	1.13	0.53	0	7
Female	A	0.55	0.5	0	1
Age	A	54.82	18.29	16	90
Education	A	0.37	0.48	0	1
Urban	A	0.59	0.49	0	1
Local government level explanatory variables					
Compatibility (log)	B	3.85	0.66	2.51	4.93
Attitude	C	28.66	10.21	11	57
Labour control	D	0.44	0.5	0	1
Environmental spending per capita (log)	E	4.84	0.17	4.51	5.11
Recycling satisfaction	C	44.78	7.21	27	56

Data sources: A. Welsh Government (NSW 2016–2017); B. Communities First annual monitoring reports; C. Welsh Government (aggregated indicators based on NSW 2015–2015); D. BBC Local Elections website; E. Welsh Government.

Hastings random walk sampling via MCMC simulation techniques. MCMC sampling procedures for our multilevel models are based on $2.01*10^7$ draws with the first 100.000 draws omitted. These first draws are excluded to account for the *burn-in* period of the sampler. In addition, to decrease the autocorrelation of the simulated MCMC sample and improve the precision of the Bayesian simulations, we use a thinning factor of 100 for all chains, thus resulting in 200.000 effective MCMC draws.[4]

It should be highlighted that Bayesian methods involve choosing a prior probability distribution for the parameters before analysing the data, such choice being the object of substantial debate in the related literature (see, e.g., Berger 2006; Browne and Draper 2006; Efron and Morris 1972; Gelman 2006). Prior distributions can range from informative descriptions of previous research, to non-informative priors based on little previous knowledge about the effect under analysis (Gill and Witko 2013). Given the few empirical studies addressing the question of what factors motivate citizens' co-production, we decided to use weakly informative priors in our MCMC simulations. In particular, we use a Normal$(0, 10^4)$ prior for the 'fixed' parameters of the model, and a half-Cauchy prior with mode at 0 and scale set to 30, for the variance hyperparameter (see, Gelman 2006).

Results

In this section, we present the estimates of our empirical models. We begin by fitting a varying-intercept[5] multilevel model including only individual predictors (model 1) and we then add the local government level variables (model 2). Before reporting and discussing our results, it should be noted that, from a Bayesian perspective, statistical inference can be performed through an analysis of the posterior distribution. Hence, we report in Table 2 posterior means and standard deviations for the statistical models and, to further facilitate results' interpretation, we show in Figures 1 and 3 the posterior probability densities for both multilevel models, approximated by kernel density estimation. In addition to the Bayesian approach, we also report results of

Table 2. Multilevel Poisson estimates of factors influencing environmental co-production.

	Model 1		Model 2	
	Mean	Std. Dev.	Mean	Std. Dev.
Individual level explanatory variables				
Carer	0.0601	0.0187	0.0576	0.0149
Self-efficacy	0.0125	0.0078	0.0130	0.0074
Civic engagement	0.0954	0.0145	0.0965	0.0106
Female	0.0320	0.0177	0.0343	0.0140
Age	0.0264	0.0029	0.0260	0.0026
Age Squared	−0.0003	0.0000	−0.0003	0.0000
Education	0.2163	0.0183	0.2162	0.0080
Urban	−0.1050	0.0216	−0.1056	0.0158
Local government level explanatory variables				
Compatibility (log)			0.0485	0.0242
Attitude			−0.0011	0.0016
Labour control			−0.1313	0.0356
Environmental spending per capita (log)			−0.2111	0.0082
Recycling satisfaction			−0.0048	0.0017
Random effects				
Level 2 Variance	0.0066	0.0032	0.0034	0.0021
N (individuals)	4,957		4,957	
N (local governments)	22		22	
Acceptance Rate	0.30		0.31	
MCMC Effective Sample	200,000		200,000	

Note: A constant term is included in all models.
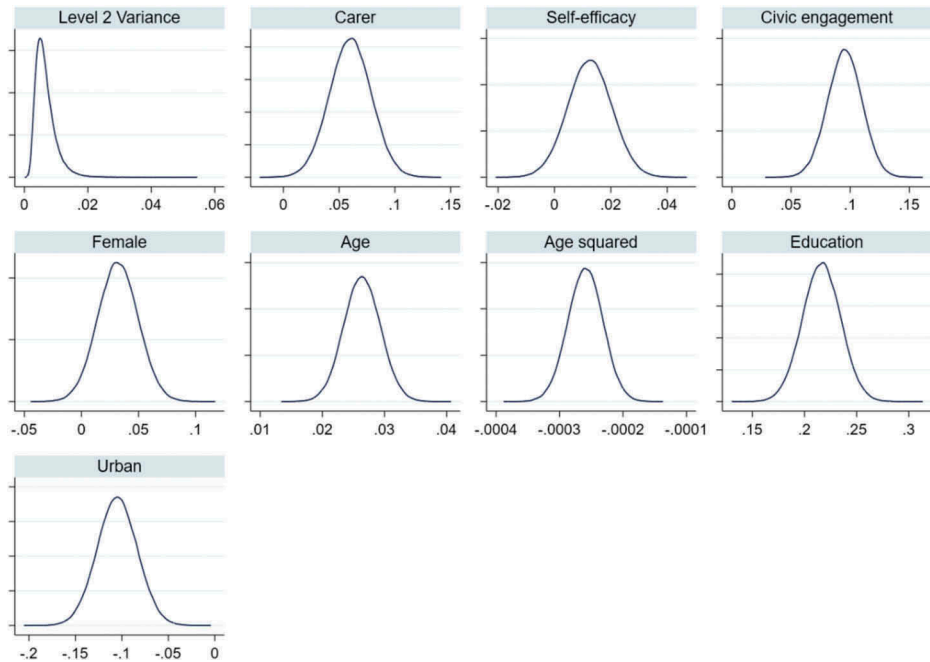
Figure 1. Posterior densities of each parameter for Model 1.

estimating the same multilevel models using ML techniques (see Table A1 of the Appendix). Although, as discussed, ML techniques might perform worse in our case,

they offer a benchmark to check the robustness of the results to different estimation methods.

Individual factors affecting the probability of co-producing environmental outcomes

We begin our empirical analysis by testing which citizens' characteristics might influence the probability of engaging in co-production activities. Consistent with our expectations, being a carer, the degree of civic engagement, and holding a high perception of self-efficacy are important predictors of co-production behaviours. Conditional on the model and data, results for both models, i.e. models 1 and 2, show that there is a 95% probability that the coefficient associated with being a carer would be positive. Thus, in line with our theoretical expectations, a key motivator of co-production behaviour is associated with satisfaction gained from doing 'the right thing'.

Similarly, our results also suggest that intrinsic rewards such as the belief that one can positively influence local policy decisions play a key role in predicting co-production behaviours. Again, an inspection of the coefficient associated with the *self-efficacy* parameter shown in Table 2, along with the posterior probability densities depicted in Figures 1 and 3, suggest that there is a 90% probability that the parameter estimate of *self-efficacy* takes a positive value. In this line, our findings also point to a positive correlation between civic engagement and environmental co-production, i.e. the greater the citizens' involvement in volunteering networks, the greater the likelihood of exhibiting environmental co-productive behaviours; both models suggest that, conditional on the model and data, there is a 95% probability that our measure of civic engagement takes a positive value.

Moving now onto those socio-demographic characteristics predicting co-production behaviours, our results are mostly consistent with previous empirical studies; women, middle-aged citizens, the better-educated and those living in rural areas are more likely to engage in co-production activities. Among these factors, our results suggest that education and living in a rural area are particularly strong individual-level determinants of environmental co-production: the posterior means of both variables being about 0.22 and 0.11, respectively. Regarding *age*, it should be noted that the negative coefficient associated with the squared term, along with the positive coefficient of the estimates for *age*, suggest that there is a non-linear effect of *age* on environmental co-production behaviours.

Do organizational/contextual factors matter when predicting co-production behaviours?

Besides evaluating individual characteristics that may predict co-production behaviour, this analysis sought to test whether local factors could provide further explanation about the likelihood of citizens' engagement in environmental co-production activities. First, if the local context helps to explain citizen's co-production behaviours, one may expect to see a relatively wide variation in the number of co-production behaviours across Welsh LGs. This indeed seems to be the case. Figure 2 shows the spatial distribution of our co-production index by local government. Clearly, the average number of co-productive behaviours varies substantially across governments; the highest average number of co-production activities can be found in Monmouthshire,
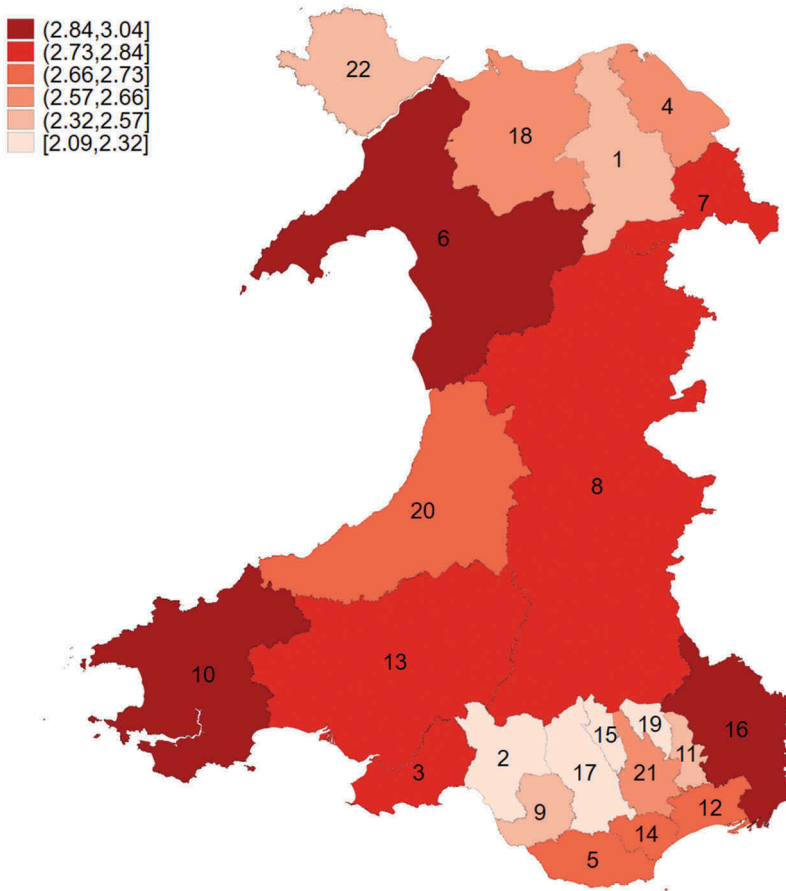
Figure 2. Distribution of environmental co-production behaviours among Welsh Local Governments. The figure shows the average co-production behaviours by local government: (1) Denbighshire, (2) Neath Port Talbot, (3) Swansea, (4) Flintshire, (5) Vale of Glamorgan, (6) Gwynedd, (7) Wrexham, (8) Powys, (9) Bridgend, (10) Pembrokeshire, (11) Torfaen, (12) Newport, (13) Carmarthenshire, (14) Cardiff, (15) Merthyr Tydfil, (16) Monmouthshire, (17) Rhondda Cynon Taf, (18) Conwy, (19) Blaenau Gwent, (20) Ceredigion, (21) Caerphilly, (22) Isle of Anglesey.

Pembrokeshire and Gwynedd, while the lowest is observed in Neath Port Talbot, Rhondda Cynon Taf, Merthyr Tydfil and Blaenau Gwent (see also the density histograms depicted in Figure A1 of the Appendix).

The results from our multilevel models confirm these initial exploratory findings. First, the LG-level variance in Model 1 (0.0066), along with the LR test comparing the multilevel model with a one-level regression depicted in Table A1 of the Appendix (p-value = 0.000), indicate that there is variation between Welsh LGs as regards citizens' environmental co-production behaviours. Furthermore, the LG-level variance is reduced when including those LG level contextual/organizational factors that might affect citizens' co-production in Model 2 (0.0034), which suggests that we were able to identify LG-level factors influencing co-production.

The output of Model 2 reported in Table 2 and Figure 3 confirms most of our expectations relating to those LG organizational/contextual factors influencing
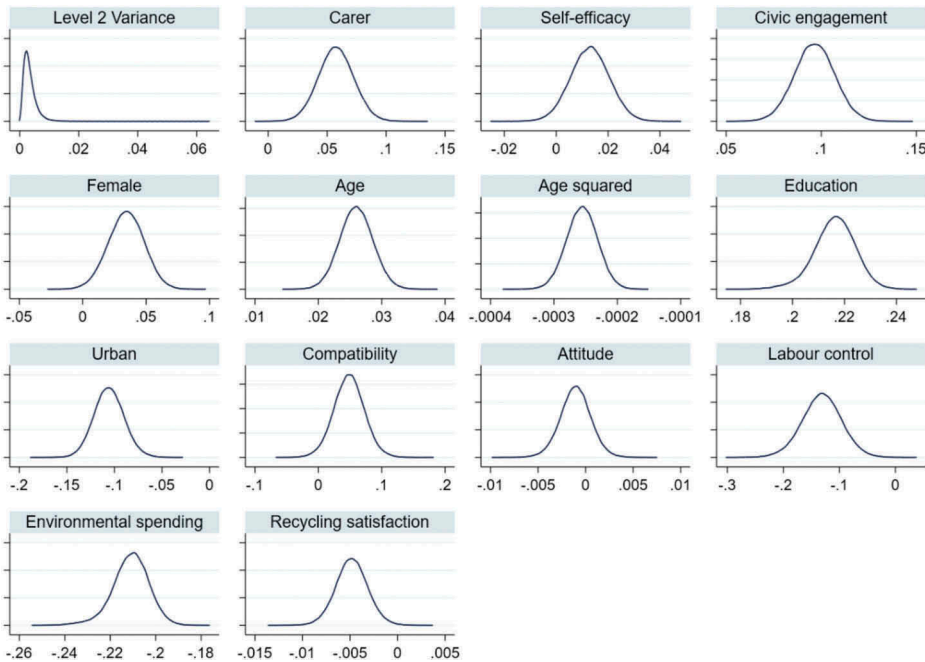
Figure 3. Posterior densities of each parameter for Model 2.

citizens' co-production. First, the *compatibility* of public organizations with respect to co-production, measured as the log of the number of Communities First partnership members, seems to explain, to a certain extent, why citizens engage in environmental co-production. The posterior mean of *compatibility* is positive (about 0.048) and the posterior probability density is clearly centred away from zero (see Figure 3). In this line, our results suggest that *administrative culture* is also an important predictor of co-production: individuals living in more risk-averse producerist LGs exhibit fewer pro-environmental behaviours as indicated by the negative posterior mean of the Labour party control dummy (about −0.13) and the density of the posterior probability, which clearly takes negative values. By contrast, we find that, conditional on the model and data, the *attitude* of public officials towards citizens' participation does not seem to predict co-production, the posterior probability density of this parameter being centred around zero.

Turning our attention to the potential influence on co-production of the quantity and quality of public services provided by the local government, we find clear evidence that this is a key factor shaping pro-environmental behaviours. The parameter estimates for our two measures of quantity and quality of public services, i.e, environmental spending per capita and citizens' satisfaction with recycling services, point in the same direction, the posterior means of all these parameters being negative and almost the whole mass of the posterior probability densities taking negative values.

Conclusion

This paper illustrates the multi-level nature of co-production: individual-level factors drive people in Wales to engage in more pro-environmental behaviours, but so too do local government-level factors. More specifically, being a carer, self-efficacy and civic engagement appear to be personal motivations that are critical to co-production, while local institutional structures, priorities and performance are organizational factors that seem to make a real difference. These findings have theoretical and practical implications.

Although demographic characteristics are important determinants of co-production, individuals' personal values and motivations also matter. From the individual-level perspective, our study provides support for theories of co-production that emphasise the motivating force of intrinsic rewards. The evidence we present here highlights that the intrinsic rewards associated with these attitudes seem to be a major influence on people's pro-environmental behaviour, underlining the value of psychological or behavioural approaches to understanding co-production (see Voorberg et al. 2018, for example). At the same time, our study confirms the role that organizations can play in facilitating or discouraging co-production.

Much of the co-production literature stresses the importance of organizational-level factors (Voorberg, Tummers and Bekkers, 2015), yet scant research systematically evaluates the connections between organizational behaviour and outcomes and citizens' co-productive activities. Our findings suggest that pro-environmental behaviours may substitute for the provision of poor quality environmental services and for risk-averse 'producer-led' public service provision. Nevertheless, they also indicate that participatory structures may be associated with positive engagement with environmental issues. This evidence therefore offers a nuanced corrective to a straightforward zero-sum viewpoint on citizens' co-production activities – co-production may be a replacement for effective state-led public services, but in the right circumstances it may be a source of additional institutional capacity as well (Needham 2008).

Practically speaking, our analysis suggests that policies intended to promote the co-production of public services may benefit from a dual approach, focused on: i) inculcating positive attitudes among citizens; and, ii) the establishment of participatory structures for citizens' engagement with local policy-making. Civic education programmes intended to engage, educate and empower citizens may boost their self-efficacy (Andrews et al. 2008b). Well-managed partnerships between public, private and non-profit organizations can potentially open up new spaces of inclusion through which citizens' influence on decision-making may be institutionalised (Bristow et al. 2008). Notwithstanding the challenges in making engagement with public policy work (Few, Brown, and Tompkins 2007), these two approaches can have positive reciprocal effects on each other. Empowered citizens may be more likely to engage with participatory structures, while involvement in participatory structures may increase a sense of empowerment.

Despite the strengths of our multi-level research design, it has limitations that open up possibilities for further investigation. Firstly, we draw upon a cross-sectional snapshot, meaning we make no definitive claims regarding causality within our study. In particular, longitudinal or experimental data is needed to establish the extent to which co-production is a response to poor provision or whether it prompts public organizations to under-provide key services (Percy 1984). Secondly, due to data limitations, we

rely on proxies for some of the measures we employ. Future studies should seek to measure all the factors potentially influencing coproduction with greater precision than we are able to on this occasion. Thirdly, although common method bias is not a serious threat to our organizational-level findings, research designs utilising different sources of data for key individual-level constructs would be valuable. Finally, our study has examined environmental co-productive activity in a single country during a specific time period. It would be important to identify whether the relative importance of individual and organizational-level factors differs for educational, healthcare or other aspects of co-production, as well as in other countries and in other time periods. Given the propensity of citizens who are carers or civically engaged to be environmentally active, it would also be instructive to investigate the correlations between citizens' coproduction of outcomes across multiple service/policy areas.

In conclusion, this study has examined the relationship between a series of individual and organizational level factors and the pro-environmental behaviour of a sample of Welsh citizens. In doing so, it highlights that a multi-level approach is needed to properly understand the determinants of citizens' co-productive activity: personal attitudes, demographic characteristics, organizational behaviour and outcomes all influence pro-environmental behaviour. These findings therefore represent an important contribution to theories of co-production in the public sector and can assist in further unpacking the ways in which public managers and policy-makers can seek to boost co-production as a vital source of social innovation.

Notes

1. For a comprehensive explanation of the survey methodology, sampling strategy, etc, we refer the reader to Aumeyr et al. (2017)
2. The Environment Strategy for Wales was published in May 2006, and described the environmental goals to achieve by 2026, and how to achieve them. The text can be accessed here: https://gov.wales/docs/desh/publications/060517environmentstrategyen.pdf. In addition, the background information for the NSW (https://gov.wales/statistics-and-research/national-survey/summary/?lang=en) highlights that 'Thes [survey] results are used by the Welsh Government to help make Wales a better place to live.' The pro-environment behaviours survey respondents identify are therefore 'co-productive' of the Welsh Government's environmental policy, especially the first goal in the Well-being of Future Generations Act 2015 – 'An innovative, productive and low carbon society which recognises the limits of the global environment and therefore uses resources efficiently and proportionately (including acting on climate change)' http://www.legislation.gov.uk/anaw/2015/2/section/4/enacted (see also, the first iteration of the NSW pro-environment behaviour questions in the Outdoor Recreation Survey https://cdn.naturalresources.wales/media/681025/welsh-outdoor-recreation-survey-key-facts-for-policy-and-practice-2016.pdf?mode=pad&rnd=131546924000000000.
3. The exception being the coefficient associated with the female dummy variable which becomes negative, a finding consistent with recent studies that suggest that men tend to participate more in formal environmental organizations (see, e.g., Garcia-Valiñas, Macintyre and Torgler, 2012). This suggests that correlates of co-production might differ between individual and group-based activities. Hence, though we are unable to confidently identify such differences in pro-environmental behaviour on this occasion, it is something worthy of more in-depth investigation across all aspects of citizens' co-productive behaviour.
4. Estimations computed using alternative numbers of draws, thinning factors and burn-in periods produced basically the same results.
5. For a comprehensive review of different types of multilevel models, we refer the reader to Gelman and Hill (2007).

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Appendix

Table A1. Multilevel Poisson Maximum-likelihood estimates.

	Model 1		Model 2	
	Mean	Std. Error	Mean	Std. Error
Individual level explanatory variables				
Carer	0.0603	0.0188	0.0604	0.0188
Self-efficacy	0.0126	0.0078	0.0128	0.0078
Civic engagement	0.0956	0.0145	0.0960	0.0145
Female	0.0318	0.0177	0.0316	0.0177
Age	0.0263	0.0029	0.0264	0.0029
Age Squared	−0.0003	0.0000	−0.0003	0.0000
Education	0.2167	0.0183	0.2139	0.0183
Urban	−0.1058	0.0214	−0.1002	0.0218
Local government level explanatory variables				
Compatibility (log)			0.0498	0.0231
Attitude			−0.0008	0.0015
Labour control			−0.1302	0.0371
Environmental spending per capita (log)			−0.2225	0.0834
Recycling satisfaction			−0.0044	0.0019
Random effects				
Level 2 Variance	0.0045	0.0020	0.0014	0.0010
N (individuals)	4957		4957	
N (local governments)	22		22	
Log-likelihood	−8497.76		−8490.51	
LR-test (p-value)	0.000		0.021	

Note: A constant term is included in all models.

Table A2. Multilevel Poisson estimates of factors influencing environmental co-production: individual-based activities only.

|	Model 1		Model 2	
	Mean	Std. Dev.	Mean	Std. Dev.
Individual level explanatory variables				
Carer	0.0552	0.0190	0.0546	0.0179
Self-efficacy	0.0071	0.0079	0.0073	0.0078
Civic engagement	0.0913	0.0149	0.0878	0.0134
Female	0.0389	0.0179	0.0411	0.0170
Age	0.0261	0.0030	0.0254	0.0014
Age Squared	−0.0003	0.0000	−0.0003	0.0000
Education	0.1983	0.0185	0.1957	0.0173
Urban	−0.0934	0.0218	−0.1040	0.0115
Local government level explanatory variables				
Compatibility (log)			0.0540	0.0210
Attitude			−0.0014	0.0014
Labour control			−0.1184	0.0172
Environmental spending per capita (log)			−0.2106	0.0358
Recycling satisfaction			−0.0036	0.0021
Random effects				
Level 2 Variance	0.0059	0.0029	0.0032	0.0021
N (individuals)	4,957		4,957	
N (local governments)	22		22	
Acceptance Rate	0.30		0.30	
MCMC Effective Sample	200,000		200,000	

Note: A constant term is included in all models.
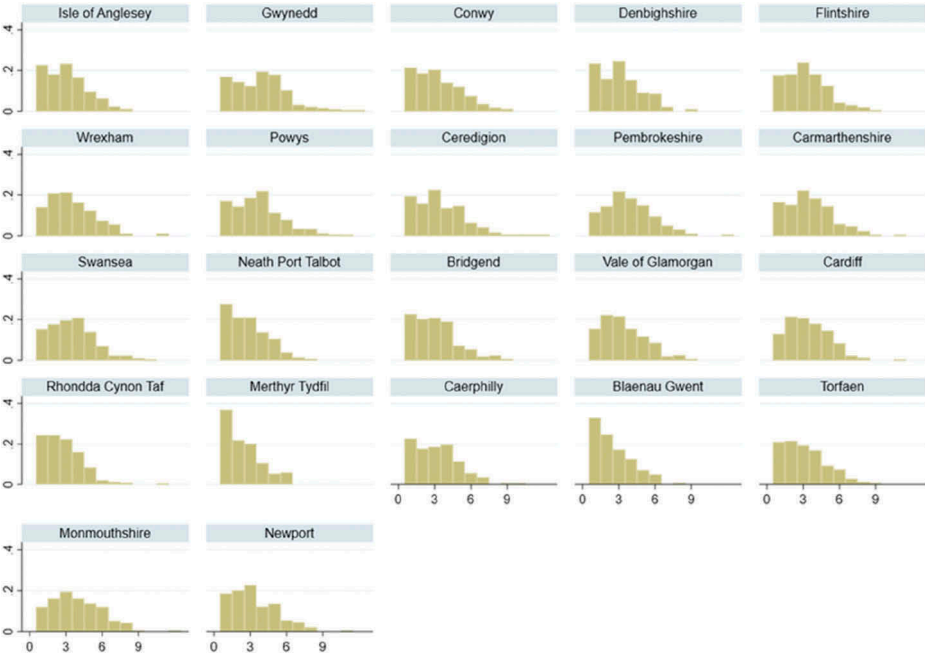
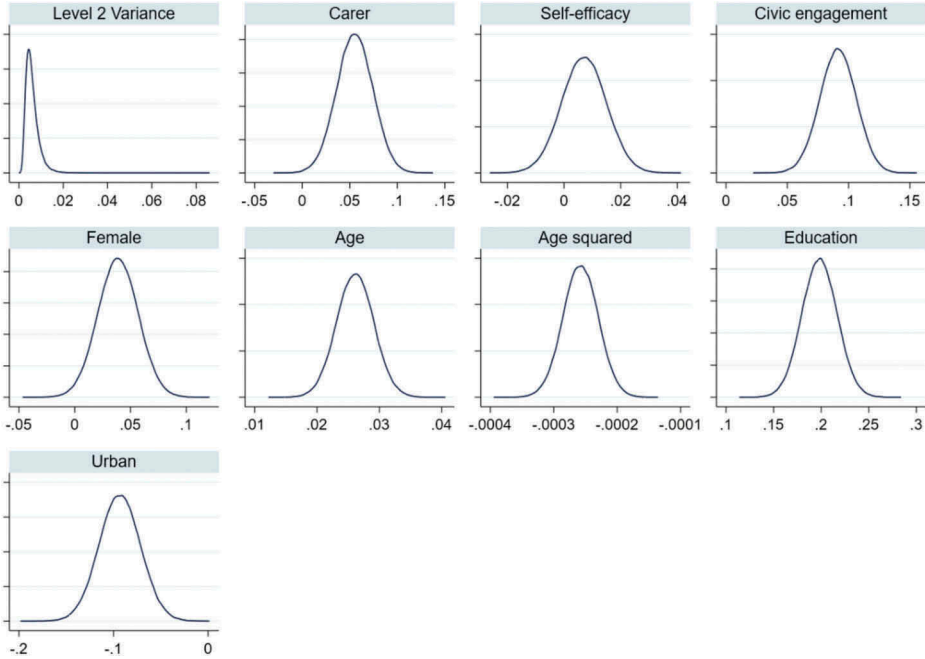**Figure A1.** Density histograms of the co-production index by local government.

Figure A2. Posterior densities of each parameter for Model 1. Dependent variable: individual activities.
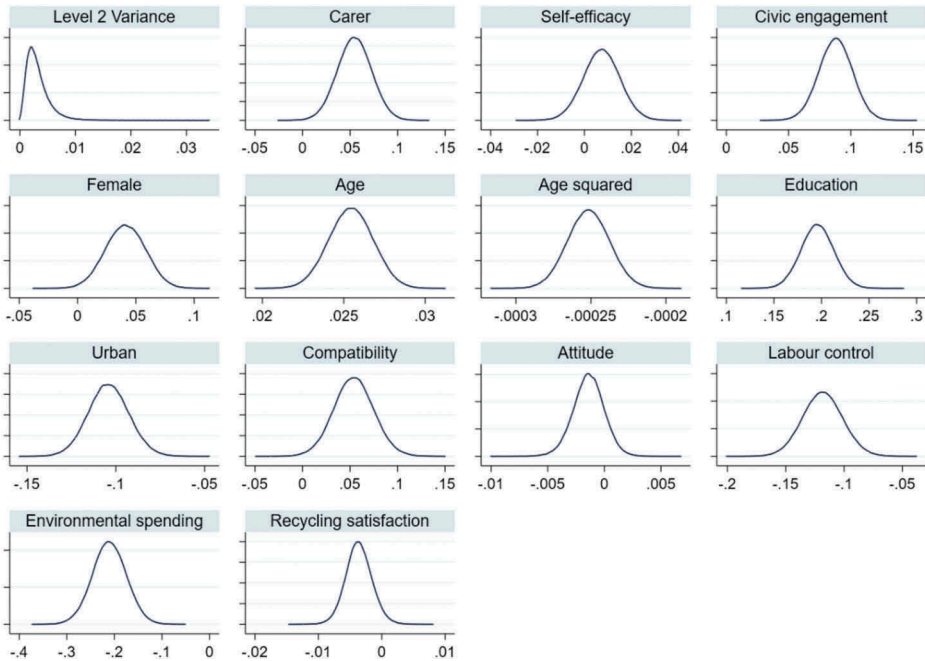
Figure A3. Posterior densities of each parameter for Model 2. Dependent variable: individual activities.