


Estimating urban food waste at the local level: are good practices in food consumption persistent?

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Abstract Although the recent empirical literature provides a satisfactory range of estimates of food waste at the national and global level, little attention has been devoted to lower units of aggregation. This article tackles the phenomenon of urban food waste (UFW), proposing an analysis of consumer behaviour at the local level. Using institutional data for Italian provinces, over an 11-year time span (2004–2014), we estimate the amounts of UFW and subsequently investigate the extent of persistence and spatial spillovers using the local Moran transition probability matrix. Our results suggest that the good and bad practices in food consumption that determine the levels of UFW are persistent over time. Moreover, they produce a (though limited) spatial spillover, affecting consumption practices in the neighbouring areas. Two province clusters emerge, one in Northern and Central Italy, featuring negative behaviours and the other one in South-Central and Southern Italy, displaying virtuous behaviours. This situation calls for public policies aimed at promoting convergence in the levels of UFW.

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1 Introduction

Food waste has recently been recognised as one of the key risk factors for the global environment, as well as an obstacle to long-term economic growth (Sobal and Nelson 2003; Lipinski et al. 2013; Parry et al. 2015). The food sector alone accounts for about one third of the greenhouse emissions in the EU (Garnett 2011), posing a relevant threat with respect to global warming. In the recent years, the UN estimated that about one-third of the total world production of food was lost or wasted (Gustavsson et al. 2011; Buzby and Hyman 2012; Thyberg and Tonjes 2016). Food waste represents a twofold problem: on the one hand, it entails a sub-optimal use of natural resources, fostering economic inefficiency and resource depletion; on the other hand, it generates costs related to waste disposal (Morone et al. 2016). All these points urge for the adoption of food waste reduction strategies, which have become a priority for many national governments and international organisations (Pearson et al. 2013; Platt et al. 2014; Priefer et al. 2016). In the EU, food waste is conceptually defined as any edible or inedible part of food that is removed from the supply chain and eventually disposed (Östergren et al. 2014). Over the last decade, several measures have been undertaken by public actors, aimed at promoting and spreading virtuous behaviours in order to reduce food waste (FAO 2014a). Most governmental actions in this field mainly resorted to fiscal instruments—either taxes or subsidies¹ (Mazzoni 2013; Katare et al. 2017; Kravitz 2015). Other somewhat popular instruments included regulation, impositions of standards and mandatory labels, communication campaigns and educational programmes (OECD 2008). Awareness is the point on which *soft* governmental measures have been focusing over the last two decades, through educational campaigns and programmes targeting consumers (Priefer et al. 2016). Such programmes are meant to help consumers make correct shopping decisions as well as handle, prepare and store food efficiently (Porpino et al. 2015). The most famous campaign is the UK’s ‘Love Food, Hate Waste’, launched in 2007 (Questa et al. 2011). Over 5 years, it contributed to reduce food waste in Britain by 21%. Other similar initiatives have followed in France, Germany, Denmark, Catalonia and Portugal. The environmental literature has shown a positive relation between economic development and environmental awareness (Franzen and Meyer 2010). In spite of an increasing degree of awareness however, attitudes are likely to turn into behaviours only under

¹ In the US for example, although no federal tax on food disposal currently exists, counties and localities have introduced disposal taxes: this is the case of Seattle, Washington (Katare et al. 2017; Kravitz 2015). Elsewhere in the world, national level taxes have been imposed, e.g. in South Korea (Mazzoni 2013). Fiscal benefits on the other hand have recently been introduced in the US (Food Recovery Act, 2016) as well as in Italy (law 166/2016), for companies that reduce waste by donating surplus food to charities.

certain specific conditions, e.g. when such behaviours are not especially costly (Diekmann and Preisendörfer 2003).

Much has been learnt about these strategies and at present there is wide consensus in the literature on the fact that the food waste phenomenon must be tackled on both sides of the market: all along the production chain, producers and retailers need to share information and responsibility, working together towards goal of a lower waste level (Pfaltzgraff et al. 2013; Göbel et al. 2015); on the other hand the determinants of consumer behaviours need to be fully disentangled to devise effective policy instruments to guide their choices (Griffin et al. 2009; Jörrissen et al. 2015). Consumers are of vital importance not only due to their purchase and consumption decisions, but also for their general perception of food, which in turn influences heavily the industry standards (Rutten et al. 2013; Aschemann-Witzel et al. 2015). Along with public policy agendas, the public opinion has grown more and more concerned about devising strategies to reduce food waste (Questa et al. 2013a, b; Monier et al., 2011), meaning consumers themselves have become more aware of the urge to tackle the problem (Neff et al. 2015).

Despite the lack of a universal definition, food waste may be roughly quantified at 1.3 billion tons per year (Monier et al. 2011), of which 88–89 million tons per year are produced in the EU-27 (BCFN 2012; Stenmarck et al. 2016). The European average is estimated at about 180 kg per capita a year (Monier et al. 2011; O'Connor 2013), although much variation is attested among the EU countries (see Fig. 1). While the Netherlands generated almost 600 kg per capita in 2010,—i.e. more than three times the EU average—Malta and Greece kept their levels below 61 kg per capita, which means they produced less than one-third of the EU average. Italy fared well enough, producing less than 150 kg per capita (BCFN 2012) and ranking in the lower half of the distribution.

Significant within-country variation is reported in the Peninsula, where Southern regions feature lower consumption and waste levels (Mazzanti et al. 2008). The South differs in many regards from Northern and Central regions, namely in terms of both economic performance and cultural traits (Putnam et al. 1994; Tabellini

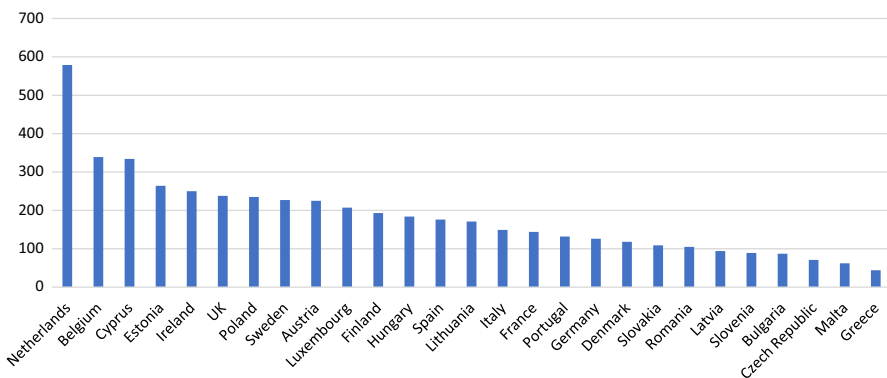


Fig. 1 Food waste in 2010 in the EU countries (kg/capita) Source: our elaborations on data provided by the BCFN (2012)

2010; Guiso et al. 2008). Both factors may contribute to explain the different levels of food waste. We focus on cultural traits, which shape pro-environmental behaviours (Crociata et al. 2016). Individual pro-environmental behaviours are often shared by social groups: in a survey at the individual level on recycling behaviours, virtuous citizen reported that 95% of their friends and neighbours were virtuous as well (Oskamp et al. 1991). Citizens surrounded by virtuous neighbours feel part of a positive mechanism when they adopt pro-environmental behaviours, whereas citizens surrounded by anti-environmental behaviours only perceive the costs of virtuous behaviours (Carlson 2001). However strict the governmental measures, individual incentives towards pro-environmental behaviours are more affected by what is considered a social standard than by the law (Bilz and Nadler 2014). In other words, in some cases cultural traits can be more binding than formal constraints (Guiso et al. 2016). Intuitively, the formation of cultural traits relies on interactions among individuals and on transaction costs, whose extent is related to geographical proximity (Fazio and Lavecchia 2013). Common values and beliefs gradually arise in the local communities that constitute disaggregated administrative units—e.g. municipalities or provinces—before nations. It is then reasonable to expect some degree of stickiness and spatial correlation in consumption practices, including food waste.

This work investigates the role of temporal and spatial patterns in the virtuous and negative consumption practices that underlie food waste. We wonder to what extent pro-environmental behaviours are spatially related and persistent over time. We compute the local Moran transition probability matrix (LMTPM) for Italian provinces to highlight the role of *neighbours*. The rest of this paper proceeds as follows: Sect. 2 provides an unambiguous operational definition of urban food waste (UFW), in line with the recent EU standards, and shows how we calculate UFW levels for the Italian provinces. In addition, it outlines the methodological instruments we employ, drawn from the spatial econometrics literature. In particular, it presents the LMTPM, which allows us to investigate the presence of spatial dependence patterns in consumer behaviours. Section 3 presents our results, highlighting spatiotemporal persistence patterns. Section 4 discusses our findings in the light of the recent literature and outlines the policy implications of this work. Section 5 offers our concluding remarks and some cues for further research.

2 Methods

In this section, we present the methods employed to investigate the spatial persistency of good/bad practices concerning UFW at the local level in Italy. First, based on the definition of UFW promoted by the European FUSIONS project (Östergren et al. 2014) we calculate UFW levels for Italian provinces, using governmental data (Sect. 2.1). Then, we wonder whether the presence of good/bad practices in a certain province affects the consumption behaviours—and thus UFW—in the nearby provinces, or on the contrary whether good/bad practices unfold independently of those of the neighbouring areas. In other words, we investigate the presence of spatial dependence patterns. To gauge the extent of

spatial effects, we apply the LMTPM to the UFW estimates, looking for spatiotemporal persistence in the distribution of good/bad practices (Sect. 2.2).

2.1 Urban food waste estimates

In this section, we present the definition that we use throughout this work and subsequently we measure UFW for the Italian provinces, based on data drawn from ISPRA (Superior Institute for Environmental Protection and Research).

At the EU level, the critical task of developing a harmonised definition of food waste has been entrusted to the FUSIONS (Food Use for Social Innovation by Optimising waste prevention Strategies) project that, in July 2014, released the ‘FUSIONS definitional framework for Food Waste’ (Östergren et al. 2014). The definition of food waste provided by FUSIONS and consistently used in this article is the following: ‘Food Waste is any food, and inedible parts of food, removed from the food supply chain to be recovered or disposed (including composted, crops ploughed in/not harvested, anaerobic digestion, bio-energy production, co-generation, incineration, disposal to sewer, landfill or discarded to sea)’.

This official definition largely differs from the earlier outlines found in the literature (Lebersorger and Schneider 2011). First, the focus is on the ‘Food Waste’ expression, rather than on terms such as ‘Food Wastage’ and ‘Food Loss’, widely used by previous works. (Waarts et al. 2011; Parfitt et al. 2010; Gustavsson et al. 2011; Kummu et al. 2012; BCFN 2012; Lipinski et al. 2013; FAO, 2013b, 2014b, c; Bagherzadeh et al. 2014). In addition, the FUSIONS outline sets aside a variety of commonly used terms, e.g. ‘avoidable/partially avoidable/unavoidable’ food waste (Qusted et al. 2013a, b; Qusted and Parry 2011; Qusted and Johnson 2009; Cordingley et al. 2011; Mason et al. 2011; Viel and Prigent 2011; BCFN 2012; Katajajuuri et al. 2012); ‘edible/inedible’ food waste (Reisinger et al. 2011); ‘edible/potentially edible/unedible’ Food Loss (Møller et al. 2012); ‘wanted/unwanted’ Losses (Somsen 2004); ‘Food and Drink Waste’ (Qusted et al. 2013a, b; Qusted and Parry 2011; Qusted and Johnson 2009); ‘Post-Harvest Loss’ (Hodges et al. 2011); ‘Spoilage’ (Lundqvist et al. 2008); ‘Kitchen Waste’ (Sonnino and McWilliam 2011); ‘Wastage’ (Lundqvist et al. 2008; Redlingshöfer and Soyeux 2012; FAO 2013a, b); ‘Surplus’ (Garrone et al. 2012) and many others (see Annex C in Östergren et al. 2014).

The fraction of non-edible food (e.g., peels, fish-bones, bones, and other non-edible parts of animals and crop production) falls within the food waste definition proposed by FUSIONS, whereas the fraction used in the production of animal feed is excluded. This choice contrasts with many approaches used in the literature and with the FAO standards (FAO 2013b, 2014b, c), that exclude the non-edible fraction of food and include the fraction of food waste generated when producing animal feed. Including the non-edible fraction of food yields two advantages: (1) the measure is not affected by cultural, social and religious factors and (2) it is easier to measure, since it is not obvious to quantify separately the edible and the inedible fractions.

Although this theoretical framework is rather clear, it is still tricky to estimate food waste in practice. In Italy, domestic food waste, i.e. the waste produced at the

household level, is composed by both the edible and the inedible fraction of: (1) the food purchased but not consumed and discarded in the garbage; (2) the food eliminated in drains; (3) the food used in domestic composting. The data on these three flows are not available separately (Azzurro 2015). In particular, the food waste flow is difficult to measure, given that domestic waste is managed together with the waste resulting from businesses and restaurants. For these reasons, we focus on of UFW, i.e. the one generated in the consumption stage, either by households or by shops and restaurants, including school canteens and hospital cafeterias. UFW is expressed in kilograms per capita. Following Azzurro (2015), we use ISPRA data on organic waste, assuming that the percentage of UFW found in the sorted and unsorted waste is constant over time.²

$$\text{UFW} = 0.184 * \text{OWNCS} + 0.59 * \text{OWCS} \quad (1)$$

where OWNCS is the share of organic waste found in the waste that is not collected separately and OWCS is the percentage of organic waste deriving from the separate collection of urban waste.³ A concern that may arise is related to the fact that not all provinces feature the same level of separate waste collection, which might lead us to overestimate UFW in the provinces where separate collection is more pervasive, notably the ones in Northern Italy (see Sects. 4 and 6.2 in the Appendix for more details).⁴

Although we follow Azzurro (2015), this work features some important differences:

1. We propose a UFW measure at the provincial level (NUTS-3), rather than at the national level.
2. We work with a dataset covering 11 years (2004–2014) and not a single year.
3. We propose a per capita measure of UFW, thus assessing more thoroughly the dimension of the phenomenon.

The great advantage in disaggregating data at the provincial is that we manage to model spatial spillovers more properly (Arbia 1988, 2005; Arbia et al. 2002; Agovino et al. 2016). Moreover, the availability of data for more than a decade enables us to gauge the magnitude of the spatiotemporal persistence of good practices in the prevention of UFW.

2.2 Local Moran transition probability matrix (LMTPM)

A first step in the spatial dynamic analysis is represented by the LMTPM, that provides a measure of the degree of spatiotemporal persistence of food consumption practices. Its entries show the Local Indicators of Spatial Association (LISA) transition probabilities, i.e. the probabilities that a province belonging to class i at

² The weights were taken from Azzurro (2015).

³ Due to space constraints, we do not report the calculations lying behind our UFW estimates, but all the information is available upon request.

⁴ We thank our referees for pointing out this problem. Further research should try to take this issue into account.

time t , ends up belonging to class j at time $t + 1$ (Le Gallo 2004; Le Gallo and Ertur 2003). The LMTPM is based on the integration of the local Moran statistic (Moran 1950) obtained from our estimates, into a Markov transition matrix (Rey 2004) and allows us to know whether a province and its neighbours occupy, in terms of UFW, the same quadrant or a different quadrant of the Moran scatter plot, over the period analysed. This method has been used only in a few studies: Rey (2004) applied it to the US per-capita GDP, Le Gallo (2004) did the same for GDP disparities in European regions, Fazio and Lavecchia (2013) employed it when studying social capital and trust, Agovino (2014) used it on the labour market of people with disabilities, and Agovino et al. (2014) resorted to it when dealing with urban environmental quality.

In a single period, i.e. 1 year in our case, the local Moran statistic may take on four values, which means there are sixteen possible transitions between two different periods (Rey 2004). These sixteen transitions can be grouped into four classes:

- the first class (type I transitions) includes only transitions characterised by the relative movement of a province while its neighbours do not move, e.g. a **HH** province in the first period (t) that becomes a **LH** region in the next period ($t + 1$). The remaining cases are: $HL \rightarrow LL$, $LH \rightarrow HH$ and $LL \rightarrow HL$;
- the second class (type II transitions) includes the transitions in which the local province does not move, while the neighbouring provinces change their value: $HH \rightarrow HL$, $HL \rightarrow HH$, $LH \rightarrow LL$, $LL \rightarrow LH$;
- the third class (type III transitions) includes transitions in which both the local province and its neighbours move: $HH \rightarrow LL$, $LL \rightarrow HH$ (type IIIA transition), $HL \rightarrow LH$, $LH \rightarrow HL$ (type IIIB transition);
- the fourth class (type IV transitions) includes transitions in which both the local province and its neighbours keep their value: $HH \rightarrow HH$, $LL \rightarrow LL$, $HL \rightarrow HL$ and $LH \rightarrow LH$.

Notice that the arrow indicates the transition, while the bold letter indicates the region that moves. These results are summarised in Table 1.

The concepts of *spatial cohesion* and *spatial flow* are related to the LMTPM (Rey 2004). Spatial cohesion is defined as the sum of the frequencies of the type IIIA and type IV transitions (the cases in which one province and its neighbours move in the same direction).

$$C_t = \frac{F_{IIIA,t} + F_{IV,t}}{n} \quad (2)$$

where $F_{IIIA,t}$ and $F_{IV,t}$ are, respectively, the number of transitions of type IIIA and type IV in the period $t \rightarrow t + 1$ and $n = F_{IV,t} + F_{I,t} + F_{II,t} + F_{III,t}$.

Spatial flow is defined as the frequency of transitions of type I and type II during the transition period. Consequently, a high stability in the transition type is reflected by low spatial flow values.

$$F_t = \frac{1}{nT} \sum_{t=1}^T (F_{I,t} + F_{II,t}) \quad (3)$$

Table 1 Local Moran transition probability matrix
Source: Rey (2001)

$t/t + 1$	HH_{t+1}	HL_{t+1}	LH_{t+1}	LL_{t+1}
HH_t	IV	II	I	IIIA
HL_t	II	IV	IIIB	I
LH_t	I	IIIB	IV	II
LL_t	IIIA	I	II	IV

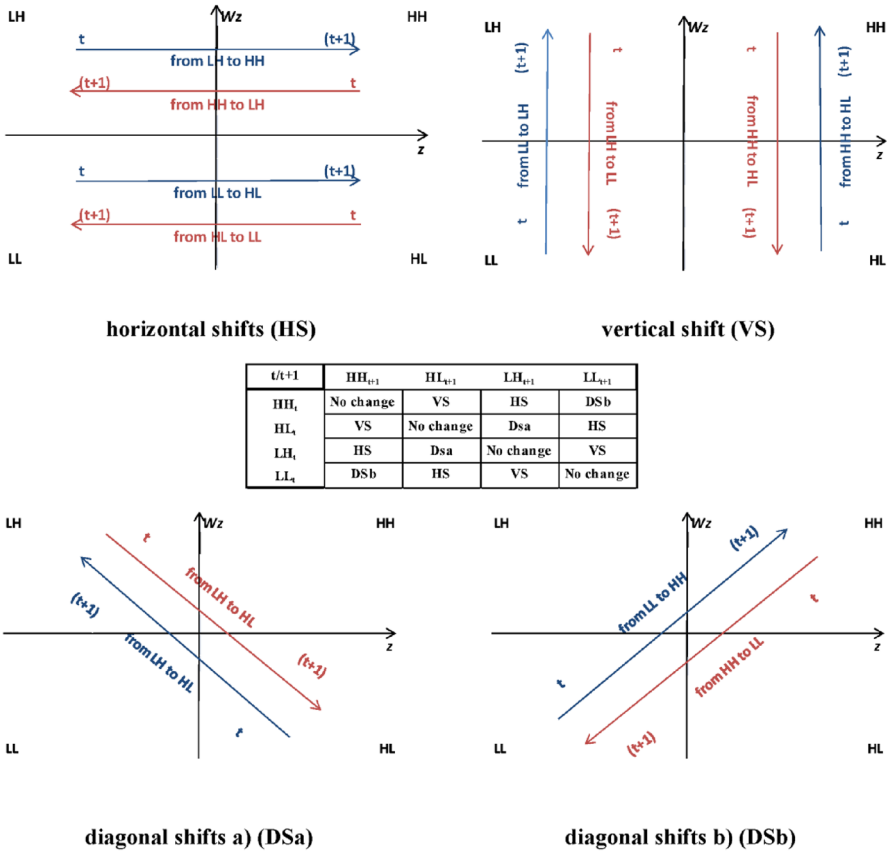


Fig. 2 Interpretation of the transitions

where $F_{I,t}$ and $F_{II,t}$ are, respectively, the number of transitions of type I and II in the period $t \rightarrow t + 1$, $n = F_{IV,t} + F_{I,t} + F_{II,t} + F_{III,t}$ and T is the period analysed (2004–2014) (Fig. 2).

The central table represents the LMTPM and it indicates the type of transition that the local province undergoes over a certain period. Each element of this matrix indicates the probability of a movement type (Rey 2001). Changes in the local province without any changes in neighbouring provinces yield *horizontal shifts* (HS)

from quadrant LH to HH (or HH to LH) or from HL to LL (or LL to HL). Changes in the neighbouring provinces without any changes in the local province yield *vertical shifts* (VS) from quadrant LH to LL (or LL to LH) or from HH to HL (or HL to HH). Changes in both the local province and its neighbours are associated with *diagonal shifts* (DSa and DSb) from quadrant HH to LL (or LL to HH) and LH to HL (or HL to LH) (see Fazio and Lavecchia 2013). All these movements correspond to the off-diagonal values on this matrix, showing the probability of spatial change. Finally, the values on the main diagonal indicate transitions in which both provinces and their neighbours remain in the same class. The LMTPM results allow to distinguish between provinces that improve their food waste levels in relation to their neighbours, provinces whose performance worsens, and provinces that persist in their original situation.

3 Results

In this section, we apply some tools and concepts borrowed from spatial statistics to the UFW estimates obtained in the previous section. Our purpose is twofold: (1) to offer a general picture of the current situation in terms of good/bad consumption practices at the provincial level and (2) to identify spatial patterns.

3.1 Preliminary analysis on urban food waste

The box maps display our estimates of UFW across the Italian provinces, considering the quartiles of the distributions.⁵ In particular, Fig. 3 shows how good practices (UFW < 25% of the distribution, i.e. first quartile) and bad practices (UFW > 75% of the distribution) tend to cluster over the years. While in 2004 the UFW levels look like a highly fragmented patchwork, in the subsequent 4-/6-year intervals, a clear clustering trend emerges, in which the provinces in Central Regions (Tuscany, Umbria and Marche) and Northern Regions (Emilia-Romagna, Veneto and Lombardy) are those with the highest UFW levels (UFW > 75% of the distribution, i.e. fourth quartile), while the provinces in South-Central Regions (Latium and Abruzzo) and in the South (Campania, Puglia and Calabria) are the ones with the best consumption practices (UFW < 25% of the distribution). The distribution of UFW on the Italian territory suggests a spatial diffusion process is taking place for both good practices (South-Central and Southern Italy) and of bad practices (Central and Northern Italy). A few other provinces here and there display good practices, but they are dispersed and the cluster that they form does not go beyond the regional borders. This is the case of Valle d'Aosta and Trentino Alto Adige.

⁵ A key parameter in the box map representation is the hinge value. The hinge determines the spread of acceptable values displayed as horizontal lines above and below the Inter Quartile Range (IQR) box. We chose a hinge value of 1.5, meaning the acceptable data extends ($1.5 \times \text{IQR}$) away from the median line. Any values outside the hinge spread are considered outliers (De Smith et al. 2007).

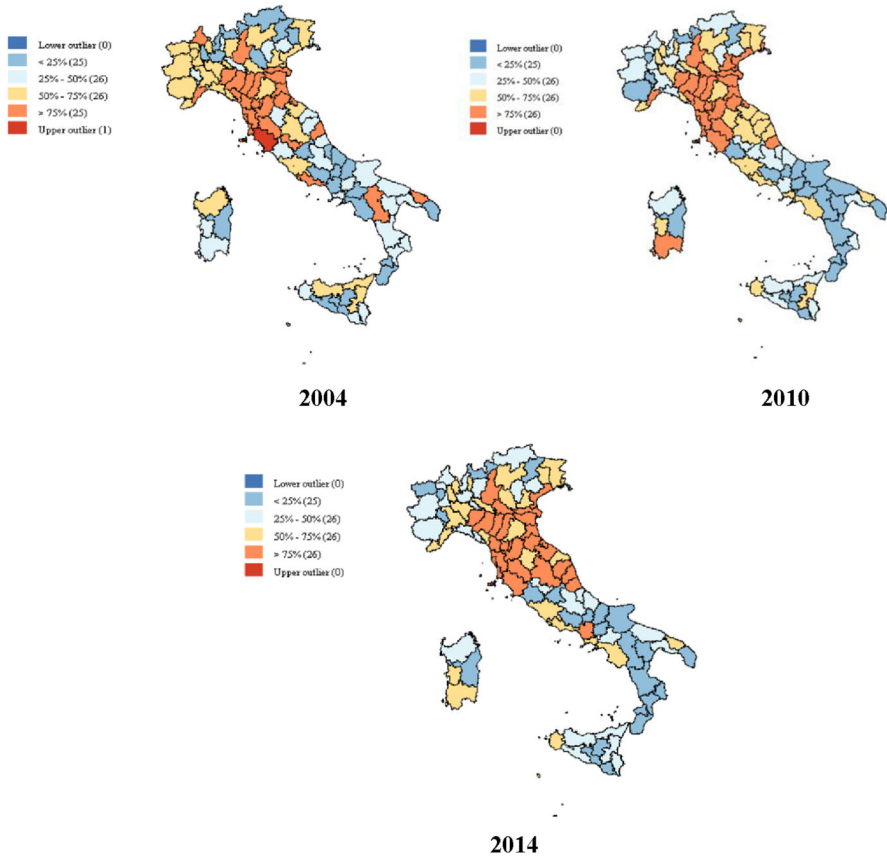


Fig. 3 Box maps of UFW, 2004, 2010, 2014 Source: our elaboration on ISPRA data

We conclude this section with the implementation of the Moran scatterplot⁶ (Anselin 1993) for UFW. The Moran's I coefficient of spatial autocorrelation is indeed strongly related to the LMTPM (see Sect. 2.1). More specifically, Moran's index is defined as follows:

⁶ The Moran scatterplot provides a tool for visual exploration of spatial autocorrelation (Anselin 1996, 2002a). The four different quadrants of the scatterplot identify four types of local spatial association between a province and its neighbors:

- (HH) a province with a high UFW surrounded by neighbors with high UFW (quadrant I);
- (LH) a province with a low UFW surrounded by neighbors with high UFW (quadrant II);
- (LL) a province with a low UFW surrounded by neighbors with low UFW (quadrant III);
- (HL) a province with a high UFW surrounded by neighbors with low UFW (quadrant IV).

Quadrants I and III pertain to positive forms of spatial dependence while quadrants II and IV represent negative spatial dependence (Rey and Montouri 1999).

$$I = \frac{\sum_i \sum_j W_{ij} (x_i - \mu)(x_j - \mu)}{\sum_j (x_j - \mu)^2} \quad (4)$$

where μ is the average value in the sample, x_i and x_j indicate the variable describing the phenomenon under investigation, in province i and in province j respectively, and W_{ij} is the corresponding entry of the standardised spatial contiguity matrix, which specifies the criteria for defining proximity. In this work, as common in the literature, we use a Queen First Order contiguity matrix (Anselin 1988). This index allows us to establish the relationship existing between a phenomenon observed in province j and the same phenomenon observed in contiguous provinces.

The Moran scatterplot in Fig. 4 shows the Moran's I coefficient as the slope of the regression line in the scatterplot, where food waste lies on the horizontal axis and its spatial lag is on the vertical axis (both variables are standardised). Figure 4 shows positive values of the Moran's I coefficient for each of the years we consider. Namely 0.4369 in 2004, 0.5475 in 2010, and 0.5196 in 2014. This result indicates positive spatial correlation for food waste levels (Anselin 2002b).⁷ A clear spatial diffusion process emerges, as the provinces are mostly distributed between the first and third quadrant (see footnote 2).

Overall, the graphs highlight the existence of a spatial relation among Italian provinces in terms of UFW. In particular, Fig. 4 shows the extent of spatial spillovers among contiguous provinces. Subsequently, we investigate spatiotemporal persistence. In order to do so, we test the following hypotheses:

H1: Whether there is a convergence process in local consumption practices (average UFW), where good practices imply low UFW, while bad practices mean high UFW;

H2: Whether the Italian provinces tend to form two clusters placed at the extremes of the UFW distribution, yielding a bimodal distribution (polarisation), or whether they tend to form more than two clusters, i.e. yielding a multimodal distribution characterised by stratification;

H3: Whether a dispersion of UFW levels among all classes can be interpreted as divergence (Le Gallo 2004).

To test these hypotheses, in the next section we use the ergodic distributions obtained by implementing the LMTPM analysis.

3.2 LMTPM results

Using the UFW estimates produced in Sect. 2.1, we obtain the LMTPM. We consider the transition of UFW states between two consecutive periods of time. In our analysis, we have ten possible transitions in the period 2004–2014 (i.e. 2004–2005, 2005–2006, ..., 2013–2014).

⁷ The Moran's I test, implemented on UFW for each year analysed, always rejects the null hypothesis of spatial independence. We do not show for brevity the results, but they are available upon request.

Fig. 4 Moran scatterplot of UFW, 2004, 2010, 2014. FW stands for urban food waste, while W_FW represents the spatial lag

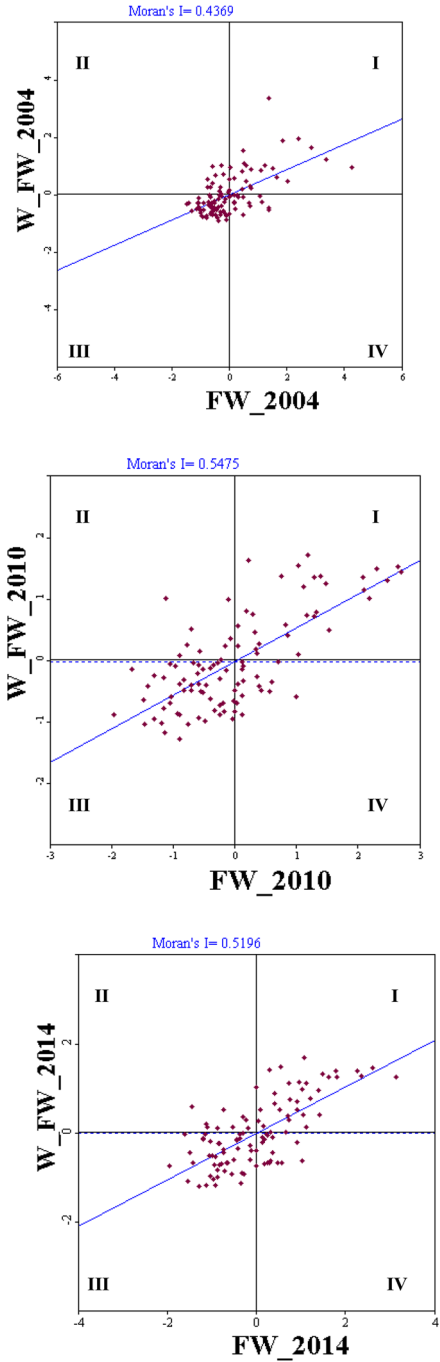


Table 2 shows the transition matrix. The transition probabilities on the main diagonal are relatively high. Indeed, if a province is in the i th class in year t , the probability of being in this same class in year $(t + 1)$ is at least 63%. The diagonal elements dominate, especially among HH and LL classes (i.e. the first and the third quadrant of Moran scatterplot, respectively). These results indicate that a province with high UFW surrounded by neighbours with high UFW (HH) and a province with low UFW surrounded by neighbours with low UFW (LL) are very unlikely to change their relative positions over time, which points to a certain degree of persistence of both good and bad practices (Fazio and Lavecchia 2013). The other elements on the main diagonal, namely HL and LH still feature the highest values in their rows, yet are smaller with respect to the probabilities associated with the HH and LL classes. This leaves some room for spatial change, possibly via neighbour imitation. For instance, provinces in the HL class at time t (i.e. provinces featuring high levels of UFW surrounded by ‘virtuous’ provinces), have a probability of roughly 0.63 to stay in their own class, of 0.21 to move to the LL class (i.e. to improve their current status) and of 0.13 to move to the HH class (i.e. to affect their neighbours negatively). This suggests a positive influence by the neighbours on the province and simultaneously a negative influence by the local province on its neighbours. Provinces in the HH class are much less likely to improve their performance: they have probability 0.87 to stay in their own class and 0.05 to move to the LH class. This seems to depend on the role played by neighbours.

There is no impressive move from year to year, since only strictly positive elements are observed around the diagonal. In addition, we consider the ergodic distributions that can be interpreted as the long-run distribution of UFW (last row of Table 2). The ergodic distributions are more concentrated around the HH and LL classes and this indicates the existence of a bimodal distribution featuring polarisation, since the frequencies in the HH and LL classes are the highest.

Table 3 displays the probability of transition types. We can observe that the probability associated with type IV transitions, i.e. P (type IV), is the highest: this reveals a high persistence in terms of good and bad practices. The stability of the results is ensured by the low value of the spatial flow (0.171); the high spatial cohesion (0.820) is an additional confirmation of the fact that a province and its neighbours tend to move in the same direction, either persisting in their original status (type IV) or switching status together (type IIIA).

Table 2 LMTPM of the UFW

$t \rightarrow t + 1$	HH	LH	LL	HL	Number of observations
HH	<i>0.872</i>	0.052	0.042	0.035	288
LH	0.165	<i>0.661</i>	0.142	0.031	127
LL	0.015	0.043	<i>0.852</i>	0.090	467
HL	0.128	0.034	0.209	<i>0.628</i>	148
Ergodic distribution	0.338	0.117	0.406	0.140	

The largest value in each row is presented in bold. Italicized values indicate permanence in the same situation over the years

Table 3 LMTPM: probability of transition type

Type	n	P (type)
Type IV	826	0.802
Type I	109	0.106
Type II	67	0.065
Type III	28	0.027

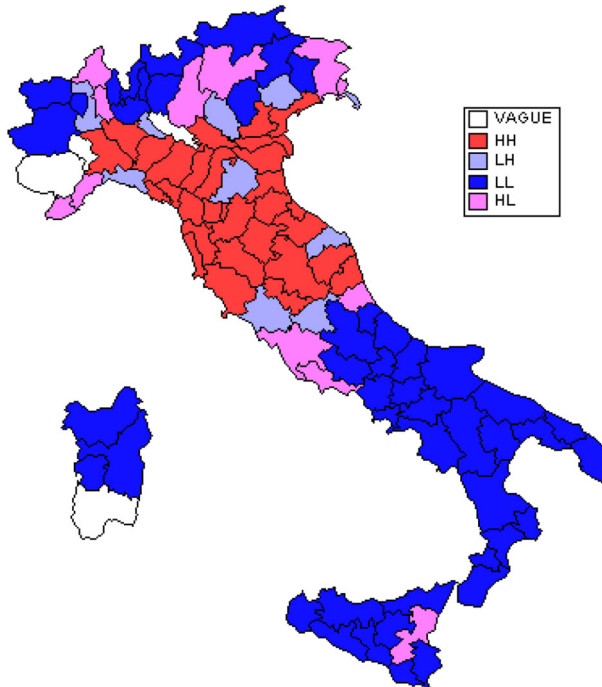
**Fig. 5** LMTPM summary measures: local Moran distribution. “Vague” denotes the provinces that are equally distributed among the four classes and do not allow for an unambiguous allocation

Figure 5 shows the spatiotemporal persistence in the Italian provinces in terms of UFW in the years 2004–2014. In other words, the allocation of the provinces to one of the four classes of the LMTPM (bearing in mind that the four classes of the LMTPM correspond to the four quadrants of Moran scatterplot in Fig. 4) happens according to the number of years during which the provinces remain in one of the four classes. For example, if one province, in the 11 years of analysis (2004–2014), remains for 10 years in the HH class and for 1 year in the LH class, it will be allocated in the HH class.

Figure 5 can be employed for the identification of local clusters (provinces where adjacent areas have similar values) or spatial outliers (areas distinct from their neighbours). In particular, for the period covered, we observe that:

- Italian provinces mainly end up in either quadrant I or quadrant III of the Moran scatterplot, reflecting HH and LL clustering, respectively;
- two strong provincial clusters emerge, and they are persistent for all the 10 years considered. The first one is the Northern and Central Italy cluster and it is characterised by provinces with high UFW (i.e. bad practices in terms of UFW) surrounded by neighbours with high UFW (HH), each of which shows up mostly in quadrant I. The second cluster is the South-Central and Southern Italy cluster and it is characterised by provinces with low UFW (i.e. good practices in terms of UFW) surrounded by neighbours with low UFW (LL), each of which belongs to quadrant III when its local Moran coefficient is significant.

These findings show a polarisation process in which the Italian provinces tend to form two clusters placed at the extremes of the UFW distribution. The effect of a persistent dualism on UFW is an interesting result to be studied in view of a reduction of food waste through a convergence process towards good practices, which are already present in the Southern provinces.

4 Discussions

Our results corroborate the idea that good practices and bad practices in food consumption are persistent at the local level, since they are deeply rooted in the cultural background that shapes daily individual behaviours. We also show that geography matters to some extent when it comes to determining consumption practices: both good and bad practices are spatially related, possibly yielding a *contagion effect* across provinces, as already pointed out in the recent empirical literature (Agovino et al. 2016; Crociata et al. 2016; Gezici and Hewings 2007).

The factors that determine consumer behaviours may be divided in two groups: (1) personal motivations and beliefs and (2) socio-demographic conditions. The former group includes awareness, information and attitude—in other words the intrinsic individual incentives towards reducing food waste, based on ethical or cultural values which go beyond mere money saving—as well as practical knowledge on how to handle, cook, store and dispose food. Younger generations largely lack skills and know-how in food management and often incur in problems like failing to interpret expiry dates or to store vegetables correctly (Papargyropoulou et al. 2014; Halloran et al. 2014; Cox and Downing 2007; Terpstra et al. 2005). This means there is some room for public intervention in the provision of information on how to select, cook and store food. It is however crucial to choose the right channels to make sure the information is delivered and to keep sending the same messages, since consumers tend to forget easily over time (Aschemann-Witzel et al. 2015). Socio-demographic variables on the one other hand include economic factors as well as *social norms*. Intuitively, areas featuring higher income levels tend to waste more food because households are less careful in avoiding waste; areas featuring lower income levels instead tend to waste less because households face a higher opportunity cost of wasting food (Nordlund and Garvill 2002). Similarly, the existence of a social norm influences consumes, penalising anti-environmental

behaviours (Kaiser and Fuhrer 2003). The penalty associated with negative behaviours however may decrease significantly if such they constitute a standard in nearby areas (Bilz and Nadler 2014).

Our analysis shows a strong North–South divide in terms of food waste levels, which may be primarily due to the relevant income gap between the two areas—Northern and Central provinces feature higher income levels than Southern provinces. In part, the divide may also depend on the operational definition we used for UFW, since we put a higher weight on the organic waste resulting from separate collection. Separate collection is more widespread in Northern and Central regions, possibly leading us to overestimate food waste in those areas.⁸ Separate waste collection facilities in particular are less available in the South, implying that higher amounts of organic waste may end in the unsorted waste, which has a lower weight in the framework of our estimation strategy (see Sect. 6.2 in the Appendix for more details).

Social norms are another potential factor at play, which would also explain the presence of spatial effects, i.e. the fact that consumers in a certain province are influenced by the behaviours of consumers in the neighbouring areas. The overall influence of social norms however depends on the observability of the behaviours considered. Some consumer behaviours are easy to spot, e.g. the recycling of paper, plastics and glass, whereas others, like food waste prevention are less visible (Barr 2007; Cecere et al. 2014; D’Amato et al. 2016) and hence less affected. Micro-level investigations focusing on households would disentangle more thoroughly the extent to which social norms and peer effects make a difference. Other explanations may as well account for the spatial effects we detect, including emulation, i.e. the tendency to imitate the virtuous behaviours featured by neighbours (Buccioli et al. 2013), and waste tourism, i.e. the fact that some residents may find it optimal travel to neighbouring areas and dispose their unsorted waste there, in order to avoid local-level sanctions (Buccioli et al. 2015).

Compared to the rest of the EU however, Italy is a virtuous country (BCFN 2012). Depending on how food waste is measured, estimates range between 90 and 150 kg a year per capita (BCFN 2012; Garrone et al. 2015), of which only 46 kg pertain to the final consumption stage (Principato et al. 2015). Good consumption practices are largely widespread in Southern Italy and parts of Central Italy. On the one hand, this is due to the overwhelming diffusion of the Mediterranean diet, which prescribes relatively low amounts of meat. As well as having a large impact in terms of land and water use, meat consumption is associated with higher levels of food waste (Martin and Danielsson 2016). On the other hand, the large GDP increase that took place in the 1950s years did not translate into an equally large increase in food consumption, leaving local diets mostly steady (Turrini et al. 2001).

Alongside favourable consumption habits rooted in the cultural background, the normative apparatus is considered among the Best Practices in Europe (Azzurro 2015). The so-called *Law of the Good Samaritan* (Law n.155/2003) made it easier for retailers to donate unsold food to charity organisations. The rules on food

⁸ We thank our referees for pointing out this issue. Further research should take into account difference in the extent of separate waste collection.

recovery for non-profit organisations, were simplified by treating the NGOs like final consumers rather than companies. This law boosted recovery activities as well as the amounts of food recovered from school and company canteens all over the country (Falasconi et al. 2015). In 2013, a new reform (Law n.147/2013) established the standards in terms of safety for the exceeding food to be given to charity organisations and was quickly followed by the issue of a handbook explaining in detail the operational aspects that guarantee a correct storage and transportation of the surplus. In August 2016, the most recent measure on the matter (Law n.166/2016) established a system of incentives aimed at rewarding virtuous producers and distributors. Donating food was made even easier, especially when mislabelled but not risky, while investing directly on food education programmes. In order to reduce food waste in restaurants, the once rather rare ‘doggy bags’, which used to suffer from a widespread social stigma, were restyled and rebranded as ‘family bags’ and made favourable for restaurants to offer customers. As opposed to what happened a few months earlier in France, incentives were preferred over fines. Such governmental measures are at least in part responsible for the general trend of reduction in the UFW, emerging from our research. The policy trajectory however shows a certain change in the instruments the government tends to resort to: from mere regulation towards education and public awareness. As shown in the recent literature on public policy, governmental actions targeting mindsets are far more effective than those targeting behaviours (Bilz and Nadler 2014). This is why raising awareness and providing consumers with the right set of tools will be two key points in the food waste reduction strategy that the Italian government will have to resort to, similarly to what has been happening over the last 10 years in the other Western European countries.⁹ Proper information campaigns are of the essence and need to be designed (Cecere et al. 2014; Giroto et al. 2015; Priefer et al. 2016). Our analysis stresses the importance of devising locally-tailored measures to tackle food waste in different socioeconomic context. Virtuous areas may as well work as a comparative benchmark to guide public action (Buccioli et al. 2014, 2015).

5 Conclusions

This work provides estimates of UFW for the Italian provinces over the 2004–2014 timespan, using institutional data on waste collection at the local level. We look for space and time persistency patterns and we notice the existence of two clusters of provinces: one characterised by good practices in Southern Italy and the other one featuring bad practices in Northern Italy. Since the majority of the food waste in developed countries takes place at the household level, food waste prevention strategies must largely focus on consumer behaviours. Our results suggest that neighbours play a relevant role in determining the extent to which good practices in food consumption in a certain province catch off. This calls for region-specific

⁹ Apart from the already mentioned ‘Love Food, Hate Waste’ programme promoted by the British government, similar initiatives took place in other EU member states: ‘Qui jette un oeuf jette un boeuf’ in France, ‘Zu gut Fur die Tonne’ in Germany, ‘Stop Spild af Mad’ in Denmark, ‘De menjar, no en llencem ni mica’ in the autonomous region of Catalonia, in Spain, ‘Movimento Zero Desperdicío’ in Portugal.

measures, taking into account the local peculiar characteristics in terms of cultural background, social norms and dietary habits, which vary widely all-over the Italian peninsula.

Good practices do exist already, mostly in the cluster that encompasses Southern Italy and part of Central Italy, where the prevalence of the Mediterranean Diet is more pervasive. Such virtuous behaviours may as well work as a comparative benchmark to look at when trying to harmonise UFW levels all-over the Peninsula. Our empirical analysis leads the way to further research in the field of food waste reduction. An appealing idea would be to undertake a similar spatial analysis, though controlling for the socio-economic factors that drive food waste, such as household expenditure on consumption goods, dietary habits, composition of the population and social participation.

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Appendix

Some clarifications on the estimation of urban food waste

The two components of UFW are determined in this way:

$$\text{OWCS} = \text{OWCP} + \text{OWADP} + \text{OWSWC}$$

where OWCP = Amount of organic waste effectively present in the organic waste (wet + green) treated in composting plants. The calculation considers a percentage of 4.5% of impurities in the organic waste (wet + green) treated in composting plants (Centemero et al. 2013). Therefore, OWCP is 95.5% of the organic fraction in the organic waste (wet + green) treated in composting plants; OWADP = Amount of organic waste effectively present in the organic waste (wet + green) treated in anaerobic digestion plants. The calculation considers that the percentage of green plus the percentage of extraneous fractions in the organic waste (wet + green) treated in anaerobic digestion plants is equal to 10% (Centemero et al. 2013). Therefore, OWADP is 90% of organic waste (wet + green) treated in anaerobic digestion plants; OWSWC = Amount of organic waste effectively present in the organic waste deriving from separate waste collection subjected to treatments different from composting and anaerobic digestion. The calculation considers that the percentage of organic waste from separate waste collection is equal to 50% (see Azzurro 2015). This percentage corresponds in terms of weight to about 59% of organic waste from selective collection of municipal waste and OWNCS = X% of the waste not collected separately.

The ISPRA data (2013) relating to the fractions produced by mechanical biological treatment plants are considered to be representative of the product breakdown of Urban Waste not collected separately. We assume that the organic waste within these merchandise fractions is represented (by weight) by the following items: non-composted organic fraction; biostabilised; biodried; organic

fraction; scraps and leachates. So, considering the amount of these items over the total, we obtain a percentage of the organic waste produced within the undifferentiated fraction that enters as input in the mechanical biological treatment plants (e.g., equal to $Z\%$). In addition, Azzurro (2015) assumes a division between the green and organic fraction similar to the one previously estimated for the organic waste from separate waste collection of municipal waste (59% of wet and 41% of green). Assuming that these percentages are applicable to the total of the waste not collected separately, this percentage is equal to $X\% = Z\% \times 59\%$ (where 59% is the percentage corresponding to OWSWC).

Separate waste collection by region

Table 4 shows the percentage of waste that ends up being collected separately in each of the 20 Italian regions. The overall trend is positive, largely thanks to governmental measures. However, the within-country variation is still remarkable. North-eastern regions (Trentino Alto Adige, Veneto and Friuli Venezia Giulia) boast the most impressive results, while the majority of the Southern regions (especially Sicily, Calabria and Molise) lag behind. The differences in the extent of separate waste collection depend on a number of factors, including the availability of separate collection facilities and the different local policy bundles. Much variation is attested in local recycling policies, which have been recognised as more

Table 4 Separate waste collection in Italian regions (%)
Source: ISPRA (2016)

Region	2011	2012	2013	2014	2015
Piedmont	51.4	53.3	54.6	54.3	55.1
Valle d'Aosta	41.9	44.8	44.8	42.9	47.8
Lombardy	49.9	51.8	53.3	56.3	58.7
Trentino Alto Adige	60.5	62.3	64.6	67	67.4
Veneto	61.2	62.6	64.6	67.6	68.8
Friuli Venezia Giulia	53.1	57.5	59.1	60.4	62.9
Liguria	28.6	30.9	31.5	34.3	37.8
Emilia Romagna	50.1	50.8	53	55.1	57.5
Tuscany	38.4	40	42	44.3	46.1
Umbria	36.8	42	45.9	48.9	48.9
Marche	43.9	50.8	55.5	57.6	57.9
Latium	20.1	22.4	26.5	32.8	37.5
Abruzzo	33	37.9	42.9	46.1	49.3
Molise	16.3	18.4	19.9	22.3	25.7
Campania	37.8	41.5	44	47.6	48.5
Apulia	16.5	17.6	22.1	25.9	30.1
Basilicata	18	21.9	25.8	27.6	30.9
Calabria	12.6	14.6	14.8	18.6	25
Sicilia	11.2	13.2	13.3	12.5	12.8
Sardinia	47.1	48.5	50.9	53	56.4

fruitful in the North. Veneto represents a positive benchmark, featuring an incentive system that proved to be particularly effective (Buccioli et al. 2013, 2014, 2015). Given our estimation strategy, which puts weights on the OWCS and OWNCS components *regardless of the regions*, we may overestimate UFW in Northern provinces.

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