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Towards Greener Futures: Investigating the Nexus of Social, Human, and Institutional Capital in Sustainable Waste Management

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Abstract: Sustainable development is increasingly recognized for its reliance on grassroots, bottom-up practices embedded in local communities. The economic literature has tested various influencing factors on household behaviors, such as culture or social cohesion, often considering proxies of so-called "intangible capitals" separately. This article aims to jointly consider the pivotal role of three of these potential capitals that could have a trigger effect on pro-environmental behaviors, specifically, social capital (*sc*), human capital (*hc*), and institutional quality (*iq*). In particular, our study, by adopting a PVAR approach, analyzes if and to what extent *sc*, *hc*, and *iq* influence the priority goal of increasing waste-sorting practices in the 20 Italian regions. Additionally, rooted in a robust theoretical framework, we present an in-depth analysis, with the trend of impulses from statistically significant variables—having observed the important roles played by *hc*, *sc*, and particularly *iq*, as well as the control variables GDP per capita and population density—in increasing the percentage of waste sorting. This impulse analysis suggests for policy interventions that there would be immediate effects (1–2 years) due to the improvement of our intangible capitals, but also a short duration. This suggests the need for lasting and structural interventions.

Keywords: waste sorting; social capital; human capital; institutional quality; sustainable development; PVAR

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1. Introduction

In the current global context, characterized by growing environmental alarms and concerns about the potential consequences of climate disruptions, responsible waste management emerges as a fundamental pillar for building a sustainable development path [1,2]. Among the multiple strategies (also included in Agenda 2030 [3]) adopted to address this challenge, waste separation stands out as a crucial element capable of transforming the approach to waste management. This practice, far from being a mere disposal operation, represents a form of collective commitment involving citizens, institutions, and businesses on a concrete path towards a healthier environment and improved quality of life [4].

In the last two decades, the global population has grown rapidly, doubling in size, while waste production has tripled [5]. This exponential demographic expansion, especially in urban areas, along with the lack of sustainable consumption patterns and the increased use of polluting packaging materials like plastic [6], represents significant challenges for sustainable development. One critical aspect of these challenges is solid waste management [7,8].

These challenges have led to integrated approaches, in which engineering and new waste management models are advanced approaches studied globally and integrated into local and municipal management [9].

Clearly, waste management is closely linked to factors such as production, collection methods, transportation, disposal, and potentially recycling, all of which presuppose the collaboration of various institutions and economic agents, with the goal of ensuring effective execution towards the promotion of sustainable development. It is increasingly evident that the growing complexity and size achieved in such a complex system requires a management approach that cannot rely solely on conservative and traditional methods; on the contrary, it necessitates advanced executive approaches. Therefore, strategic management emerges as the only viable solution [10].

In this context, alongside increasing awareness and active grassroots participation, efficient waste management systems are necessary to improve the current situation and protect human health and the environment, especially considering that many materials found in household waste can be recycled, thus contributing to energy and resource conservation [11].

To achieve this goal, it is necessary to encourage public participation, including that of consumer households, since individuals can have a direct impact by making waste sorting part of their daily routines [12].

Separating waste is seen as an effective solution to address issues related to solid waste production. It helps promote a circular economy, enhances community well-being, and protects the environment [13].

Although there is a general trend toward environmental awareness and conservation action, driven by education [14], the sectoral literature presents conflicting results.

Empirical studies have demonstrated the positive impact of education on participation in waste separation, suggesting that a higher level of education facilitates access to in-depth environmental knowledge [15,16]. In this context, some authors have noted a greater propensity for waste separation among more educated individuals, including women [17], compared to males and older individuals [18]. Other research has found that education level, along with income [17], has a significant impact on the intention and behavior of waste separation [19–22]. Indeed, the higher these two factors, the stronger the residents' intention to differentiate waste. Similarly, a higher level of education also entails a greater sensitivity towards the environment, enough to actively participate in daily actions that contribute to creating a better environment [23]. In contrast to the studies mentioned above, Zakianis and Djaja [24] highlighted how less educated individuals tend to separate waste more frequently compared to those with a higher level of education. Similarly, albeit less rigorously, Zhang et al. [15] found that in developing countries, the level of education does not have a significant effect on citizens' engagement in waste separation, as among the more educated, attention towards economic gain and social status prevails over sustainable waste management [16]. Another aspect that cannot be ignored when addressing environmental protection is the role of social capital within a society, which seems to have various positive effects. It reduces the costs of cooperation [25], determines the state of trust and interaction between groups [26], and facilitates the learning of knowledge and waste separation behavior by promoting cooperation [27]. This process is facilitated by the adoption of effective regulatory systems and shared social norms [28], which have a far greater effect on waste management actions in men compared to women, while social networks have a more positive impact on promoting such actions among women [29]. Wan and Du [30] observe that social capital is a promoter of pro-environmental behavior both in public and private contexts. Specifically, if the public is more inclined to respect social norms, there will be a higher degree of social participation, which will generate more pro-environment actions. However, the same authors state that while social trust has a significant impact only on private environmental behaviors, the social network particularly affects public ones.

In the context of separate waste collection, it would be desirable for individual citizens to commit themselves [31], so that local institutions provide all the resources, the processes, technologies, and policies needed to recycle for the community and the specific place in question. In this regard, various studies have focused on the role of institutions in waste management. Indeed, some authors emphasize that environmental governance

should be interpreted as the management by institutions of environmental problems [32], highlighting their responsibility in cases of inadequate waste organization [33–35]. Authors like Agovino et al. [36] have found that institutional quality is a crucial factor in reducing landfill disposal and, consequently, in the amount of waste sorting. In a more recent study, Agovino et al. [37] identified three key factors of institutional quality that underpin the implementation of effective waste sorting: "Rule of Law" (regulatory quality), "Regulatory Quality" (state of law), and "Voice and Accountability." These factors are especially pertinent for the efficient collection of organic waste, paper, glass, and plastic. Regarding the relationship between citizens and institutions, Tonglet et al. [38] believe that if individuals have good opportunities, knowledge, and structures, they are more motivated to adopt pro-environment behaviors. In this case, programs managed by public, economic, or sociodemographic agents also play a significant role. For example, if the costs of waste separation increase, the chances of implementing recyclable material collection behaviors decrease. Consider the discomfort costs, such as monetary investment [39] or extra household expenses [40], the need for new spaces, and giving up time to engage in recycling activities [41,42]. One reason could be the lack of economic resources provided by public agents who are unable to implement collection programs accessible to all citizens, etc., potentially compensated for only by a high level of individual participation and commitment to environmental sustainability.

The socio-economic literature has investigated the individual behaviors responsible for consumption that generates waste and for the attention—and deliberate intention—to reducing the same waste, such as the belief that the individual can make a difference to solve the waste problem, norms, and attitudes [11,43,44]. In this article, we explore the dynamics underlying waste separation, with reference to the indicator "sorted waste" as a percentage of total municipal waste, outlining its conceptual roots, the tangible impacts on the community, and its strategic importance in the current environmental context. The analysis will be conducted through a Panel Vector Autoregression Model (PVAR) to assess the effect of three forms of intangible capital—human, social, and institutional—on the selection of waste separation and, secondly, to assess the impact of other variables on the practice of waste management.

Our work aims to fill a critical gap in sustainability literature by jointly examining individual behaviors, sustainable policies, and the role of institutions, which are often studied separately [45–47]. By focusing on the unique characteristics that differentiate a local community from an economic–institutional perspective, we analyze the regional effects of human capital (HC) and social capital (SC). We consider the influence of local institutions, particularly the institutional quality index (IQ), and control for various demographic and economic factors.

This study specifically targets Italian regions over the period 2004–2019, aiming to identify intrinsic strengths that significantly influence waste-sorting behavior. This approach distinguishes our research from previous studies that focus mainly on economic specialization [48] or predict behavior through individual actions [28], as, according to the writer, sustainable practices, especially those related to waste separation, are the result of joint actions of all the actors in society, as only through a commonality of purpose and increased awareness of our surroundings is it possible to strive for economic and sustainable growth. By integrating these variables, we provide a comprehensive understanding of the dynamics at play, helping to make a valuable contribution to sustainable development and regional policymaking.

2. Materials and Methods

2.1. Data

The purpose of this paper is to investigate the effect of human capital (*hc*), social capital (*sc*), and institutional quality (*iq*) on waste sorting behaviors in 20 Italian regions, controlling for other known determinants by using panel data from 2004 to 2019.

The dependent variable (*wsperc*) refers to the percentage of separate collection from total collection. We use this variable because household waste separation is a relevant aspect in building a sustainable development path [1,2].

hc represents the average level of regional human capital; the positive impact of education on participation in waste separation suggests that a higher level of education facilitates access to in-depth environmental knowledge [15,16].

sc is a composite index generated by the implementation of Principal Component Analysis (PCA) based on seven variables from the ISTAT (Italian National Institute of Statistics) BES (well-being and sustainability) report in the ISTAT data set, including leisure satisfaction, security, family and peer relationships, social engagement, volunteering, and support to associations. The institutional quality index elaborated by Nifo and Vecchione [49] is a composite indicator that assesses institutional quality (*iq*) in Italy based on five groups of elementary indexes (voice and accountability, government effectiveness, regulatory quality, rule of law, and corruption) and measures the value and efficiency of institutions at a regional level [37].

Our control variables are the per capita Gross Domestic Product (*gdppro*) [50] as a measure of local economic well-being, and the population density per square kilometer (*dens*), as an increase in population also leads to an increase in waste concentration, hindering its differentiation [51] (Table 1).

Table 1. Variable descriptions and sources.

Variable	Definition	Source
wsperc	Waste sorted (% of total urban waste). Percentage of urban waste subjected to separate collection out of the total urban waste collected.	ISTAT
gdppro	Per capita gross domestic product at current prices.	ISTAT
dens	Population density. Persons per square kilometer.	ISTAT
hc	Human capital. Population aged 25–64 who have achieved at most a lower secondary level of education (percentage).	ISTAT
sc	Social capital. To represent social capital, we employed a Principal Component Analysis (PCA). A composite index was derived from various BES (economic and social indicators) variables, encompassing leisure time satisfaction, safety, family and peer relationships, social engagement, volunteering activities, and support for associations.	ISTAT
iq	Institutional quality index.	ISTAT

2.2. Method

Drawing from recent empirical studies [52–54], we apply the Panel Vector Autoregression (PVAR) methodology, which merges the Vector Autoregression (VAR) approach with panel data analysis, to explore the dynamic interplay among % of sorted collection of urban waste of total urban waste and other variables, without imposing any initial assumptions. The PVAR model treats each variable as dependent on its own past values and those of all other variables in the study. By estimating the coefficients of the panel VAR through the system Generalized Method of Moments (GMM), we delve into the variance decomposition and impulse response functions, shedding light on the reaction of waste sorted to an unexpected change in any variable and the duration of this impact.

This method leverages the advantages of both cross-sectional and time series data. Our specific PVAR model is encapsulated in a system of equations:

$$X_{it} = f_i + \Gamma(L)X_{it} + \varepsilon_{it}, \quad (1)$$

where X_{it} is the vector of our stationary variables; f_i is a vector of region-specific effects; $\Gamma(L)X_{it}$ is a square matrix polynomial in the lag operator; and ε_t is a vector of idiosyncratic errors.

The Panel Vector Autoregression (PVAR) model [55] is extensively employed in a broad range of macroeconomic research areas. This includes investigations into the dynamics of the business cycle, as detailed in studies by Canova and Pappa [56], Canova and Ciccarelli [57], and Magazzino [58]. It also encompasses the examination of global repercussions stemming from financial and economic disturbances, highlighted by research from Abrigo and Love [59]. Further applications are observed in the analysis of human capital's (notably education and workforce's) role in fostering economic growth, as demonstrated in the works of Seetanah and Teeroovengadum [60] and Sun [61]. Additionally, the PVAR approach has been instrumental in assessing the effects of government spending within developed economies, with significant contributions from Bénétrix and Lane [62], Beetsma and Giuliodori [63], and Özdoğan Özbal [64].

The panel data encompass annual macroeconomic indicators across 20 Italian regions from 2004 to 2019. The descriptive statistics are presented in Table 2.

Table 2. Statistics.

Variable	Mean	St Dev	Min	Max
wsperc	38.37471	19.38475	3.571228	74.69832
gdppro	26518.4	7070.653	15233.12	43965.46
dens	184.3927	111.8221	37.7	439.2
hc	43.77956	7.465327	28.80432	61.21517
sc	6.25×10^{-7}	0.9999987	−1.9897	3.6166
iq	0.5725667	0.2379466	0.0547838	0.982487

Macroeconomic indicators often exhibit nonstationary characteristics. Thus, adapting a time series analysis for panel data allows us to examine nonstationarity and assess cointegration relationships [65,66]. The initial phase of our analysis involves determining the stationarity of the variables, as nonstationary variables may lead to misleading conclusions. When variables prove to be nonstationary, we resort to using their first differences. Our approach includes conducting both a first and second unit root test, specifically employing the IPS test [67–70]. The outcomes of the initial second-generation unit root tests for the leveled variables are documented in Table 3. According to standard significance levels, most variables appear to be nonstationary at their levels, given the non-rejection of the null hypothesis; nevertheless, they become stationary when differentiated first, as indicated in Table 4. The first difference transformation allows us to remove the fixed effects f_i in Equation (1). More precisely, we use forward mean-differencing, also referred to as the Helmert transformation [55,71] to avoid the so-called Nickell bias [72], due to the correlation between the first-differenced lag and the first-differenced error term, which both depend on ε_{it-1}.

Table 3. Unit root test: variables in level.

Variable	IPS W-t-Bar	Maddala and Wu	Pesaran Z (t-Bar)
wsperc	1.0000	0.382	0.958
gdppro	0.9287	0.996	0.612
dens	0.4600	0.092 *	1.000
hc	0.7856	0.302	0.115
sc	0.0000 ***	0.000 ***	0.000 ***
iq	0.0079 ***	0.000 ***	0.000 ***

Our elaboration based on ISTAT data. ***, *: 1, 10%.

Table 4. Unit root test: variables in first differences.

Variable	IPS W-t-Bar	Maddala and Wu	Pesaran Z (t-Bar)
Dwsperc	0.0002 ***	0.000 ***	0.121
Dgdppro	0.0000 ***	0.000 ***	0.000 ***
Ddens	0.0000 ***	0.000 ***	0.433
Dhc	0.0000 ***	0.000 ***	0.000 ***
Dsc	0.0000 ***	0.000 ***	0.000 ***
Diq	0.0000 ***	0.000 ***	0.000 ***

Our elaboration based on ISTAT data. ***: 1%.

In other words, the Gα and Gτ statistics check whether cointegration is present in at least one panel unit; the Pα and Pτ statistics check whether cointegration is present in the entire panel.

The second step is to verify the cointegration relationships. Macroeconomic models posit a long-term equilibrium relationship between variables, which can be examined through the study of cointegration among them. To this end, the four cointegration tests proposed by Westerlund [73] have been employed to check for potential cross-sectional dependence. The first two tests (G_τ and G_α) assess the alternative hypothesis that at least one unit in the panel is cointegrated, while the latter two tests (P_τ and P_α) evaluate the null hypothesis of no cointegration within the panel as a whole. The findings presented in Table 5 support the use of first-difference estimates, as the level variables are non-cointegrated and non-stationary across both panels.

Table 5. Cointegration tests.

Statistic	Value	Robust *p*-Value
G_τ	−2.124	0.900 ***
G_α	−3.535	0.770 ***
P_τ	−7.577	0.960 ***
P_α	−2.906	0.940 ***

p-values are robust critical values obtained through bootstrapping with 1000 replications. ***: 1%.

Since there is no cointegration relationship between the (nonstationary) level variables, we proceed with the estimation of the PVAR model in first differences.

A crucial phase in the analysis involves assessing the presence of collinearity and multicollinearity issues; subsequently, an examination of the correlation matrix and the variance inflation factor (VIF) is conducted. The dependent variable, *Dwsperc*, is utilized for this purpose (refer to Table 6).

Table 6. Correlation matrix and variance inflation.

	Dwsperc	Dgdppro	Ddens	Dhc	Dsc	Diq
Dwsperc	1.0000					
Dgdppro	−0.0375	1.0000				
Ddens	−0.0192	−0.0299	1.0000			
Dhc	−0.0172	0.0041	−0.0786	1.0000		
Dsc	−0.0001	0.0421	0.1293	0.0619	1.0000	
Diq	0.0359	0.1229	0.1584	−0.1166	0.1070	1.0000
VIF		1.06	1.05	1.03	1.02	1.02
Mean VIF	1.04					

The analysis reveals minimal correlation coefficients, alongside low values for both individual and mean variance inflation factors (VIFs), suggesting a lack of collinearity and multicollinearity problems.

In the context of the Panel Vector Autoregression (PVAR) model, a critical aspect of the methodology is the determination of the optimal lag length. To address this, we employ Hansen's J statistic [74,75], a robust diagnostic tool designed to test the null hypothesis asserting that the model is overidentified in terms of its specification. This involves scrutinizing whether the selected instruments or variables are excessively numerous relative to the requirements of the model. The outcomes of this assessment are detailed in Table 7, providing insight into the adequacy of the model's specification through the lens of overidentification.

Table 7. Lag order selection criteria.

Lag	CD	J	J *p*-Value	MBIC	MAIC	MQIC
1	−16.67224	109.356	0.4454306	−462.8623	−106.644	−250.8001
2	−0.2636119	72.48962	0.4616529	−308.9892	−71.51038	−167.6144

For PVAR estimation, therefore, we use one lag (Lag 1 because J *p*-value > 1).

The test of an overidentifying restriction (Hansen's J chi^2) is equal to 109.33951 (p = 0.446); this confirms the goodness of the model fit, since the null hypothesis that the overidentifying restrictions are valid is verified ($p > 0.1$).

Subsequently, the stability of the model is verified through the analysis of the eigenvalues, which are all strictly less than one (see Table 8 and Figure 1).

Table 8. Eigenvalue stability condition.

Eigenvalue		Modulus
Real	Imaginary	
0.657948	0.2576906	0.7066116
0.657948	−0.2579906	0.7066116
0.2335079	0.5636754	0.6101277
0.2335079	−0.5636754	0.6101277
−0.2189205	0	0.2189205
0.1592612	0	0.1592612

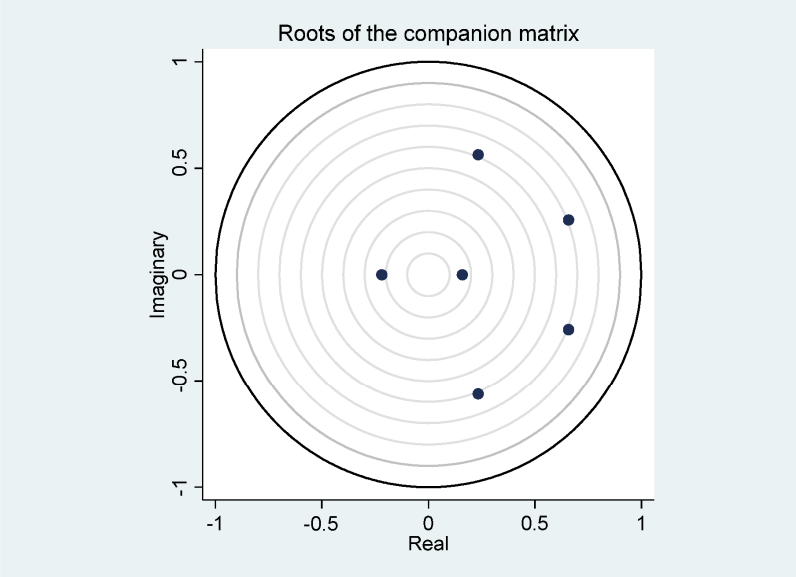

Figure 1. Roots of companion matrix.

In fact, as it is possible to deduce from Figure 1, all the roots are located inside the unit circle, thus confirming both the stability of the PVAR model and the stability of the estimated model [76].

Another step in the analysis is to perform a Granger stability test to verify the presence of endogeneity (see Table 9). A block exogeneity analysis (ALL) confirms the presence of endogeneity.

Table 9. Granger causality test.

Equation Variable	Excluded Variables	Chi^2	*p*-Value
Dwsperc			
	Dgdppro	7.157	0.007
	Ddens	8.853	0.003
	Dhc	16.341	0.000
	Dsc	11.954	0.001
	Diq	7.687	0.006
	ALL	68.107	0.000

3. Results and Discussion

We present the results for Italy (all regions) in Table 10.

Table 10. PVAR results (2004–2019).

Independent Variable: *Dwsperc*	PVAR
Dwsperc	0.2472835 ***
	(0.000)
Dgdppro	0.00037 ***
	(0.007)
Ddens	−0.0815843 ***
	(0.003)
Dhc	0.5209061 ***
	(0.000)
Dsc	0.9789447 ***
	(0.062)
Diq	6.978644 ***
	(0.006)

Test of overidentifying restriction: Hansen's J chi^2(147) = 109.33951 (p = 0.446). Note: *** $p < 0.01$.

The statistical significance of variables associated with waste separation suggests an adequate selection of regressors to explain the phenomenon of consumer households' tendency to differentiate waste in Italian regions.

First, we observe a path dependence for the phenomenon under study, suggesting the importance of entrenched trends and habits persisting over time. Such an effect could stem from awareness-raising campaigns present in Italy for years and practices that spread awareness of achievable common benefits, as highlighted in the literature [37]. Specifically, this result is among the outcomes of increasingly widespread policy actions aimed at changing behaviors towards more environmentally friendly actions, which are still under scrutiny by scholars, as well as in bridging the gaps between intentions and actual subsequent behaviors [77,78].

Second, considering the three forms of intangible capital foundational to socio-economic local characteristics, human, social, and institutional capitals exhibit statistical significance and the expected signs.

The positive relationship between education level and pro-environmental practices is widely demonstrated in the literature [79], as is the more specific connection between education and willingness to engage in waste separation [80]. A higher average level of education is confirmed to be connected to sustainable and pro-environmental behaviors [81], and in turn, higher education is useful in developing and implementing these sustainability-related processes [82]. Our findings suggest that, although a level of human capital without

specific environmental training (including individuals with secondary education) is considered, it plays an active role in the Italian context. Italy is indeed characterized by a historically low social focus on human capital development, additionally less incentivized by economic activity compared to other advanced economies, leading to an average level of human capital-related variables (e.g., tertiary education attainment) worse than many other comparable countries [83]. However, this weakness in economic and productive fields does not seem to undermine the potential role of education in other areas, such as environmental preservation and sustainability. Of course, this effect could be further strengthened by providing specific pro-environmental training, which would highlight the risks and consequences of economic agents' behaviors that impact the environment [84,85].

The role of social capital also emerges as hypothesized, and it confirms that common goals in society that would benefit all its members, such as the commitment to recycling in Italy, depend on the civic engagement of its members [45]. The functioning of social capital could influence recycling through the impetus of trust and social networks, as well as the role played by local social norms (for example, Teng et al. [86] on China). Our results therefore highlight its relevance even in the presence, for the Italian case, of the historical backwardness of this social endogenous strength in various regions of the country [87]. In our analysis, the proxy for social capital, represented through the PCA, demonstrates the predominant role of the components explaining it (see Section 2.1), confirming both the heterogeneity of social capital measures (in our case containing information from seven variables) and its predominance in explaining waste separation behaviors [88]. The mechanism of adherence to pro-environmental practices, as examined in our study, must indeed be based on social contexts, which affect social–contextual influences on public participation [89], and which is also confirmed in the functioning of social cohesion in the Italian context [90]. In addition, it should be considered that personal norms and attitudes play a mediating role between social capital and actual pro-environmental behaviors [91], and this can be integrated into future research.

In addition, the capacity and efficiency of institutional quality prove to be the major strength in the Italian case. The quality of local institutions—setting laws and regulations—covers the waste management sector and affects individuals' attitudes and subjective norms related to waste separation [92]. In addition, in a general context of increasing waste production, better management involving recycling (i.e., separation at the source) can only occur when there is cooperation among stakeholders, especially where public resources are limited [93]. In this desirable collaboration, the previously discussed social capital would also play a crucial role [94]. Our results confirm the findings of Agovino et al. [37] on Italy, which suggest that local resources, processes, and controls, among other factors, are crucial in waste management and in achieving the aim of our research question. Moreover, our results may be linked to Italy's commitment to the circular economy, confirming the responsibilities of local institutions in regulating specific legislation involving the efficiency of the waste management process [95].

Finally, the two control variables of local socio-economic contexts show the expected signals. Our findings prove that sustainable municipal solid waste management is a complex practice influenced by demographic growth and the level of economic development [96]. In particular, average income, a proxy for local development, suggests a favorable role towards better waste management practices, improving the associated facilities and enhancing environmental awareness [97]. The sign for population density is opposite, as it can lead to problems as it increases, related to the complexity of management or congestion in waste services [98].

In addition to the effects of our regressors on the trend of Italian regions towards recycling—for which the empirical evidence shows the magnitude of the effects (Table 10)—with the aim of supporting discussions and desirable policies, we provide graphs that display the trend of the impulse (Figure 2), i.e., how the dependent variable responds to changes in each independent variable over the years.

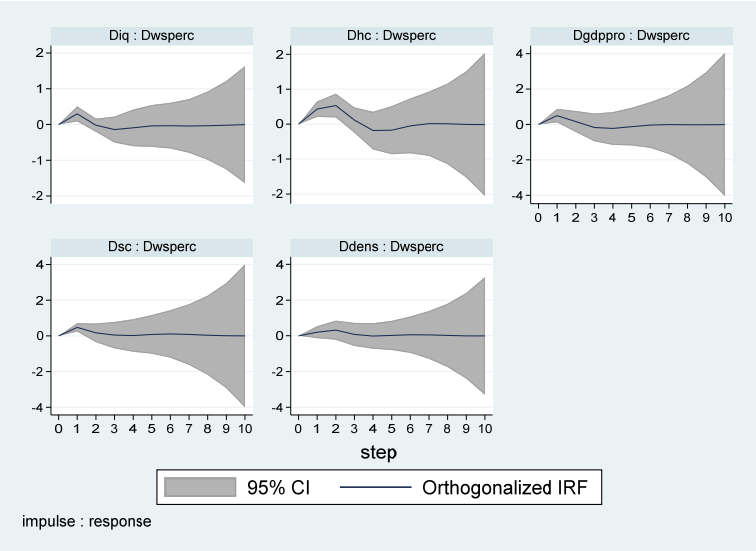

Figure 2. Impulse–responses.

More specifically, the response over time and the strength of any interventions on the regressors can be observed in Table 11.

Table 11. Summary of results.

Function	Effect on *wsperc*	Duration
gdppro	Positive	Max value: within 1st year Depletion: within 3rd year
dens	Negative	Max value: within 2nd year Depletion: within 3rd year
hc	Positive	Max value: within 2nd year Depletion: over time
sc	Positive	Max value: within 1st year Depletion: within 2nd year
iq	Positive	Max value: within 1st year Depletion: within 3rd year

The information obtained on the timing of effects, aimed at increasing the percentage of separate waste collection, reveals two contrasting sides of the coin. On the one hand, the effort to strengthen the average education, social cohesion, or institutional quality would show its effects on pro-environmental behavior in 1 (*sc* and *iq*) or 2 (*hc*) years. On the other hand, the downside is that such efforts would have short-lived results.

These results are expected and foreshadow the need for prolonged support interventions, which often contrast with the duration of political interests and governance aims. Considering the three intangible capitals, the need to strengthen the average level of education, particularly towards tertiary education (which is not yet sufficiently widespread), is an objective that many supranational institutions remind Italy of. Furthermore, the already discussed weakness of social capital in various Italian regions has historical roots. This implies a challenging response that should be structural and change habits and behaviors that are currently more in line with a "bonding" type of social capital (closed and defined within close family or kinship relationships) rather than a "bridging" type useful for socio-economic cooperation. Of course, our proxy for social capital, being the result of a Principal Component Analysis, captures the broader characteristics of this valuable endogenous strength within the system.

The quality of institutions similarly suffers from regional disparities between the north and south, which can lead to differences in the provision of services or infrastructure accessible to citizens across the country [99]. This suggests that the ongoing pursuit of greater efficiency in institutions must continue and address territorial disparities, to avoid having points of vulnerability in the economic system. In this sense, the strengthening of institutional quality at the local level has proven to be a fundamental point in Italian regions, especially those less virtuous (such as some in the southern areas) [90]. Furthermore, the ability of institutions to increase individuals' sense of responsibility [100] would also act as a kind of reinforcement to social capital.

We must also consider that the effectiveness of the three intangible capitals is not limited to the tested "green" behavior (for example, by strengthening relationships within individuals' communities [101]). These resources allow for the improvement of various sustainability efforts by consumer households, among the most important ones being the reduction of electricity and water waste [102–106], which are integrated into broader phenomena aimed at reducing society's ecological footprint, promoting a circular economy, reuse, and overall sustainability of development [107–110].

Future research will need to address these issues in light of the availability of microeconomic data on pro-environmental behaviors and the efficiency of local institutions, specifically those responsible for waste management services. In addition, it will be necessary to consider the persistence of effects stemming from both human capital (general education and environmental training) and the diverse types of social capital.

4. Conclusions

Guiding behaviors that impact the environment towards sustainable practices are crucial, given the rapid decline in natural conditions. Our study focuses on one such behavior: household waste sorting among Italian consumers. We employ a method that tackles endogeneity issues within the dependency relationship and permits an observation of the impact of each independent variable over time.

Our PVAR model highlights two key findings. First, the quality of institutions is the most crucial factor in driving the behaviors in question. This is clear given the multiple influences institutions exert: they represent the "rules of the game" that society imposes on itself and are the entities that enforce regulations and provide the necessary infrastructure for waste separation. Second, all our independent variables (which are statistically significant) show the most significant impact after 1 and 2 years. This suggests that a strong intervention by policymakers can have a relatively rapid effect.

Our "intangible capitals" can be suitable for fostering an awareness and consciousness of environmental responsibilities, but they cannot impose specific behavior, and directing behaviors towards beliefs in such practices remains a challenging subject of study. Human capital and social capital, through the awareness derived from education and social cohesion, can contribute to reducing the well-known gap between pro-environmental intentions and actual behaviors. This effect would occur because there would be a different attention to pro-social and pro-environmental issues in an automatic and constant way, leading to a real change in lifestyle. Instead, the role of institutions is to regulate and direct everyday life, making waste treatment practices, which represent a cost at various levels for those who must carry them out, more convenient. Institutional interventions can vary widely, from separation facilities to enforcement and incentives. In practice, in addition to knowledge and respect for the community and the environment (e.g., moral obligations), institutions influence citizens' awareness of consequences, and they can increase the sense of adverse consequences associated with inappropriate behaviors such as the failure to differentiate individuals' waste. Indeed, institutions must not overlook the importance of nurturing a positive image regarding environmental activities being carried out, in a self-reinforcing process of enhancing their image based on their actions (i.e., individuals' trust in institutions depends on their policies and past efficiency, how they have behaved), as well as

enhancing the knowledge of these issues, even where specialized training (an alternative aspect that reinforces general education) could be costly or challenging to disseminate.

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