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Determinants of Informal Recycling Behavior among Urban Dwellers in the Kathmandu Valley, Nepal

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Abstract

Recycling is an important tool to cope with and sustainably manage rapidly increasing waste generation, and promoting local practices such as informal recycling is vital in developing countries. This study identifies determinants of informal recycling that residents of Kathmandu Valley, Nepal practice by selling the recyclable waste to scrap dealers. The data comes from a households survey conducted with around 1200 households in the Valley in 2012. Informal recycling is important because it complements inefficient and expensive waste collection services, diverts waste from the landfill site, and helps the city to develop sustainably. We found that people who compost are 11.8 to 12.8 percent more likely to recycle in comparison to those who do not. Vegetable gardeners are significantly more likely to recycle in comparison to others. Hence, composting is a complementary behavior to recycling. This is an encouraging finding given the fact that about 65 percent of the total waste is biodegradable and municipalities can promote recycling by bundling it with the existing offer of subsidized composting bins. Another tool is institutional regulation regarding waste management; it not only avoids haphazard waste disposal but also increases recycling by 7.8 to 9.5 percent.

Keywords: Informal Recycling; Household Recycling; Recycling Behavior; Waste Generation; Composting; Kathmandu Valley; Nepal

Introduction

With an exponentially increasing urban population, solid waste management has been a significant problem in developing countries. Emerging economic development in urban areas, with its accompanying job, education, and business opportunities, attracts people to the cities. Like most urban areas in a developing country, Kathmandu Valley -the capital city of Nepal-faces the challenge of sustainable waste management. Kathmandu Valley is an economically growing and densely populated area. In 2001, around 1.6 million people lived in a 50.8 square kilometer area; i.e., 10 percent of the country's total population lived on 0.5 percent of the country's total land [1]. Waste management has become even more challenging recently as Kathmandu Valley's population grew from 1.6 million in 2001 to 2.5 million in 2011, with a population growth rate ranging from 35 to 60 percent in different districts [1], and reached almost 3 million in 2021 [1]. The rapid rate of population increase in these urban areas means that municipalities are often unable to respond to the need for increased services on time. The same is true for global urban waste management; worldwide, the population is increasing at 1.13 percent per year. The rapid increase in migration into urban areas generates huge increases in urban waste volume. Currently, global municipal solid waste generation is about 1.3 billion tons per year, and it is expected to reach 2.2 billion tons by 2025. In other words, global urban waste generation between 2002 and 2012 increased from 0.64 to 1.2 kilograms per person per day and is predicted to rise to 1.42 kilograms per person per day in 2025 [2].

Kathmandu Valley residents practice informal recycling by selling recyclable waste (such as paper, glasses, and plastic bottles) to scrap dealers and hawkers. The objective of our study is to identify what incentivizes individual households to recycle, and how their informal recycling contributes to the city's waste minimization target. This study focuses on the management of recyclable waste at a household scale. This article is important because improved sanitation is a major development goal for Nepal. Sanitation is one of the seven major development goals for Nepal, and the Sustainable Development Goal of Nepal aims to decrease the total population of those living without sanitation by half by 2015. The interim constitution of Nepal (2007) has a target to achieve universal access to water and sanitation by 2017.

In the Kathmandu Valley, common practices of managing recyclable waste are: burning it in the open air, donating it for door-to--door collection, dumping it in open spaces, river banks or streets, or collecting it and selling it to scrap dealers. All of these practices except for the last one have adverse impacts on the environment and public health. The open-air burning of plastics can create respiratory health problems. The chemical used to make rigid polyurethane foam (commonly called plastic) is called diphenylmethane di-isocyanate (MDI). Employees working on polyurethane-foam-manufacturing factories have developed hypersensitivity to MDI and suffer from many respiratory illnesses such as bronchitis, asthma, and allergies [3]. Haphazard dumping of waste litters streets and pollutes cities. Informal recycling can help reduce air pollution by avoiding open-air burning of plastics and paper, and rather selling the recyclable waste to scrap dealers.

With limited land resources and an ever-increasing population, waste minimization is the only alternative to sustainably manage waste. In 2011, Kathmandu Valley residents generated 523.8 metric tons of solid waste per day, which translates into 0.49 kilograms of waste per capita per day [4]. In Kathmandu Valley, waste reduction is minimal and almost non-existent; the majority of the waste households generate goes to the landfill site located 27 kilometers away from the Kathmandu Valley, and the landfill site has filled up before its estimated life. In the process of finding an alternative landfill site, municipalities always face public protests because people have a "not in my backyard" (NIMBY) perspective towards waste. In such scenarios, households' informal and local practices of waste segregation and recycling can minimize the amount of waste that reaches landfill sites and hence help to lengthen the life of the landfill site. Some people support part of their livelihood through informal recycling. This is not a small number: worldwide, around 15 million people make a living by picking waste from landfills or waste dumping sites.

This study is also important because informal recycling complements Kathmandu Valley's inefficient and expensive waste collection service. Kathmandu Valley's waste collection is poor or non-existent; many parts of the cities have irregular waste collection and some have none. Haphazard city planning, and hence lack of access to roads for households, makes the waste collection process logistically difficult. For example, trash trucks often cannot travel down old and narrow streets. Municipalities have to adopt inefficient waste collection systems and spend more than 50 percent of their limited municipal budget on waste collection. In informal recycling, scrap dealers hawk around households on foot or on bicycles, and buy recyclable waste. Therefore, informal recycling helps to collect waste from narrow-road households and reduce waste in a very cost-effective manner. In this regard, informal recycling is an important tool to cope with the budgetary challenges and administrative inefficiencies that municipalities face.

Informal recycling and households' role in municipal waste management, however, has not been adequately accounted for and is an overlooked topic in previous research. About 70 percent of the Kathmandu Valley's total municipal waste comes from households [5]. The existing literature on waste management in the Kathmandu Valley [4, 5], however, focuses on aggregate-level municipal waste generation and management practices. Despite its significant contribution in reducing waste, informal recycling is less captured in data and has not been analyzed quantitatively. In this study, we analyze Kathmandu Valley residents' informal recycling behavior using primary data from a household survey of around 1200 households. Hence, this study fills the research and data gap by identifying individual households' preferences and behavior regarding informal recycling. This is the first study that has captured informal recycling in Kathmandu Valley.

Identifying the factors to promote informal recycling is key to minimizing waste in the Valley. Many policy implication papers have found that promoting local resources and locally practiced behaviors makes it more successful. For example, [7] focus on the impact of informal recycling on specific urban populations who collect waste as part of their livelihood. The authors recommend that introducing formal recycling without taking into account existing informal recycling can be counter-productive.

We analyze the relationship between total waste generation and people's recycling behavior, given the unique pricing system which the Kathmandu Valley adopts. Kathmandu Valley municipalities use a fixed monthly waste collection fee irrespective of weight or volume of the waste. Unlike the unit-based pricing of waste collection (based on weight or volume of the waste), the fixed monthly waste collection fee does not provide a price incentive to reduce waste. Given this scenario, we formulate a theoretical model that captures a fixed waste collection fee and a price incentive for selling recyclable waste. The key explanatory variables that determine people's recycling behavior are the existing recycling provisions, social capital, people's attitude towards waste segregation, and other behaviors such as composting. We find that people who compost are more likely to recycle than those who do not. Hence, composting is a complementary behavior to recycling. This is an encouraging finding given the fact that about 65 percent of the total waste is biodegradable and municipalities can promote recycling by bundling it with the existing offer of subsidized composting bins. Knowledge of recycling and social capital also increases recycling. Institutional regulation not only avoids haphazard waste disposal but also increases recycling. People's caste membership also seems to influence their recycling behavior, as people who have faced past social discrimination (i.e., Dalits) are less likely to recycle than other caste groups.

In this study, we aim to provide insights and policy recommendations for achieving a sustainable urban development of the Kathmandu Valley, which can be relevant to urban areas in other developing countries as well. Our policy recommendations are focused on promoting waste reduction through recycling and hence alleviating the problem of short-life landfill sites. We expect to contribute to the development of the sustainable management of solid waste in the Kathmandu Valley. Informal recycling is an important potential tool for waste minimization because more than half of Kathmandu Valley residents (i.e., 51 percent of the total respondents in our sample) practice such recycling. Developing countries' informal recycling ranges from 20 to 50 percent; informal recycling is self-sustaining as it generates income received from selling the recyclable waste. This study explores the practical aspects of existing informal recycling services' and household practices. Our policy implications are important and practical because we do not recommend new foreign practices but rather study the feasibility of existing practices.

The Kathmandu Valley grapples with significant waste management challenges, emblematic of issues faced in many developing urban areas. As the urban population in the valley skyrockets, reaching nearly 3 million in 2021, waste management struggles to keep pace with this rapid growth. Informal recycling practices, such as selling recyclable waste to scrap dealers, emerge as a common strategy among residents. However, challenges persist, including inadequate waste reduction efforts, environmental pollution, and inefficient waste collection systems. Despite efforts to address these issues, the majority of waste still ends up in landfill sites, exacerbating the problem. Informal recycling, while prevalent, remains an understudied aspect of waste management in the valley, despite its potential to alleviate some of the burdens associated with waste disposal. This study aims to fill this gap by analyzing household recycling behaviors and identifying factors that incentivize recycling practices.

The theoretical underpinnings of our model draw upon Becker's household production function, which posits that households allocate time and resources to various activities to maximize utility. In the context of waste management, households allocate time and effort towards recycling activities alongside other productive tasks, aiming to achieve an optimal level of utility. Pollak and Wachter's revisions extend Becker's framework by incorporating considerations of leisure, environmental preferences, and technological advancements. This revised model acknowledges that households may derive utility not only from the consumption of goods and services but also from environmental stewardship and leisure activities associated with recycling. By integrating these theoretical perspectives, our empirical analysis seeks to understand the determinants of household recycling behavior and its implications for waste management policies. We examined endogeneity and determined that the overall generation of waste does not internally influence recycling. Consequently, we opt not to employ the simultaneous equation model.

The study findings indicate that waste reduction at the source through recycling is a sustainable approach for managing waste in developing country cities like Kathmandu Valley. Despite the prevalence of informal recycling practices, challenges persist, including inadequate waste segregation and burning of waste, posing health risks. Policy implications suggest that municipalities should enforce regulations, promote composting alongside recycling, and increase public awareness to boost recycling rates. These insights apply to similar contexts in other developing countries, emphasizing the importance of institutional regulation, community involvement, and public education in improving waste management practices. By understanding the dynamics of informal recycling and its role in waste minimization, policymakers can develop targeted interventions to improve waste management practices not only in Kathmandu Valley but also in similar urban settings facing analogous challenges.

Literature Review

A majority of the previous articles have studied determinants of formal recycling such as curbside recycling, transfer stations and collection of different categories of waste. Cities in developing countries do not necessarily have formal recycling services. People, however, voluntarily practice informal recycling, and hence identifying its determinants is critical. People practice informal recycling in four ways-by municipality crews, by households selling recyclable waste to itinerant buyers or scrap dealers, through street waste picking, and through dumpsite waste picking [6]. This study focuses on the second method, as the majority of households in Kathmandu Valley use this method. Households' motivation to segregate and sell waste to scrap dealers is vital in this method.

Rapidly increasing waste generation as a result of population growth makes recycling even more vital. Hence, we include a discussion of the relationship between solid waste generation and recycling. In that regard, two approaches are used in building the theoretical model regarding people's recycling behavior: a) the time allocation model based on Becker's household production function and Lancaster's consumer theory [8, 9] the solid waste generation demand model proposed by [10]. [10] allow time to be an input for household production, and an entity to produce utility for an individual. The majority of the studies have shown the inter-dependence between total waste generation and recycling. Such interdependence has been observed in two ways: i.e., total waste generation increases when the recycling rate increases; and, on the other hand, the quantity of recyclables increases when the total waste generation increases [11].

Recycling efforts have been measured in either of two forms: a) the quantity of recycled waste, or b) a binary variable representing whether people recycle or not. People's recycling efforts are modeled as an endogenous as well as an exogenous variable. For example, [11, 12] analyzed people's recycling efforts with the total waste generation as an endogenous variable. On the other hand, [13] proposed that the demand for recycling is determined within the model of the demand for waste disposal.

While identifying the factors that influence people's recycling behavior, policy variables are significant determinants. Some of these policy variables are: mandatory recycling, deposit-refund scheme, waste collection fee, waste collection frequency, and distance from one's house to the waste disposal site [14, 15]. Mandatory recycling and public awareness can effectively increase recycling. The curbside recycling and drop-off centers complement each other, and together they increase recycling [16]. On the other hand, curbside recycling and the deposit refund scheme are substitute programs, as communities with deposit-refund scheme are 18 percent less likely to implement curbside recycling [17].

A waste collection fee works as an exogenous variable inasmuch as households recycle more waste when the waste collection fee per unit by weight or volume increases [17, 18]. The positive relationship between a waste collection fee and recycling efforts represents the price incentive of a unit-based pricing structure on people's recycling behavior. Unit-based pricing is a significant incentive for people to increase their recycling efforts. However, the demand for a waste collection service is not reduced significantly [19]. As the household's recycling rate increases, the total waste generation increases, since the household reduces its source-reduction effort. On the other hand, the quantity of recyclables increases as the total waste generation increases [11]. [16] find that the variable pricing[2] of waste disposal increases the rate of recycling. Similarly, [15] find that with every $10 increase in tipping fees, [3]the likelihood of implementing curbside recycling increases by 7.8 percent. Change in the waste collection fee, however, does not incentivize people to reduce illegal disposal and increase source-reduction activities [13].

In our context, the waste collection fee is not based on weight or units as in unit-based pricing. Kathmandu Valley residents pay a fixed waste collection fee irrespective of the unit or volume of waste, and they also sell their recyclable waste to scrap dealers. A few studies that have discussed this scenario have found that such a fee structure does not give any incentive to recycling [18, 19] However, if households sell the recyclable waste, an increase in the price received from selling recyclable waste encourages households to recycle more [18]. In the debate around finding the pricing structure that gives the highest incentives for recycling, [20] favor a deposit-refund system that also allows taxing illicit burning and dumping.

Socio-economic variables influence both waste generation and recycling. For example, a bigger family size and higher income have significant positive effects on total waste generation [11]. An increase in education level has a significant positive effect on recycling, whereas increases in opportunity cost of time, represented by higher income, have a significantly negative effect on people's recycling behavior [11].

Another way to analyze people's recycling behavior is by using the theory of planned behavior and identity theory. The self-identify dimension can be an addition to the theory of planned behavior, and used to identify repeated behaviors, such as recycling. For example, attitude is a variable of the classic theory of planned behavior [21]. [22] Categorize consumer recycling behavior into four theoretical groups – intrinsic and extrinsic incentive, and internal and external facilitator[4]. Knowledge and commitment of recycling is the internal facilitator, the strongest determinant of recycling behavior. The authors identify the frequency of collection as the external facilitator that most significantly determines recycling behavior. The other factors than can sustain recycling are perceived satisfaction, commitment, and locus of control. Schultz et al. (1995) found that environmental concern motivates one to recycle when recycling requires a high degree of effort. Situational variables such as public commitment, normative influence, goal setting, removing barriers, providing rewards, and feedback also significantly increase recycling behavior.

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[1]In the unit-based pricing, the household solid waste collection fee is based on the number of bags of waste or volume of the waste disposed. In this pricing system, people have a price incentive to recycle their household waste so as to reduce the unit or volume of the total waste disposed. In this system, people also tend to reduce total waste generation through source-reduction efforts.
[2]In the variable pricing system, the waste collection fee varies over the volume of waste as well as among different blocks/communities.
[3]A tipping fee is also based on the volume of waste disposed, and hence the effect can be interpreted similar to that of unit-based pricing.
[4]Intrinsic incentives include locus of control, personal satisfaction in avoiding waste and practicing recycling; extrinsic incentives are monetary rewards for practicing recycling, social influence and commitment to recycling; internal facilitators are the cognitive variables that enable an individual to recycle, knowledge and awareness of recycling; external facilitator are time, money and effort required for recycling, and these factors can act as barriers as well.

Research Objective and Hypothesis

The objective of this study is to identify the determinants of people's informal recycling behavior in Kathmandu Valley, and to identify the relationship between solid waste generation rate and recycling behavior. The following are the hypotheses we make for this study:

H1: People with better recycling provisions are more likely to recycle. To test this hypothesis we include variables representing recycling provisions, i.e., institutional regulations, waste collection frequency, and distance from one's household to the waste collection point.

H2: People with strong social capital and more knowledge of recycling are more likely to recycle, in comparison to those without social capital and such knowledge. To test this hypothesis, we include variables representing social capital in urban areas of developing countries, i.e., participation and membership in environmental organizations or community organizations working to increase awareness about sanitation and knowledge of recycling.

H3: People with a positive attitude towards the process of recycling practice recycling more. To test this hypothesis, we include a dummy variable representing people's positive or negative attitudes about segregating waste.

H4: Composting can be a substitute or complementary behavior to recycling. In household production function, time spent on waste management related activities includes both recycling and composting [14]. We will test the relationship between composting and recycling.

Theoretical Model

The theoretical model of this paper is based on the household production function framework introduced by [8] and revised by [10]. In addition, we build upon this model partially following [10, 17]. According to Becker's household production function, an individual combines market goods and time to produce a commodity that maximizes his/her utility [8]. [10] revise the household production function where time is not only an input for commodity production but also a direct source of utility.

In the household production function, an individual household spends time in producing household goods- for example, by cooking food and recycling the waste, which is the byproduct of the household production process. Household utility function is represented as:

$$U = U\left(X, T_c, T_s\right), U_X > 0, U_{T_c} > 0, U_{T_s} < 0 \quad (1)$$

where X is the composite market good, T_c is the time spent producing household commodity, and Ts is the time spent recycling waste. An individual faces a budget constraint, given as:

$$X - pr + K = wT_w + N \quad (2)$$

In equation (2), the price of composite market goods is normalized to 1, *p* is the per-unit price of the recyclable waste households receive from selling it to scrap dealers (i.e., through informal recycling), r is the quantity of recyclable waste sold, and K represents a fixed fee for waste collection service using a conventional disposal method. [5]The right-hand side of the budget constraint in equation (2) represents the total income, which includes labor income for working T_w working hours with wage w, and the non-labor income, *N*.

[5]The Kathmandu valley uses a conventional waste disposal method, where the solid waste management fee is a flat fee that does not depend on the unit or volume of waste, unlike unit-based pricing, but this varies over communities.

An individual's time constraint is represented as:

$$T = T_C + T_S + T_w \quad (3)$$

Following Becker's household production function, the total time is allocated for producing household commodities, managing household waste through segregation and recycling, and working. Households generate solid waste, which is the by-product of household production. The technology of total waste generation and the household production is given as:

$$g = \theta X; \;\; 0 < \theta < 1 \quad (4)$$

where *g* represents the total waste generation and θ is the waste transformation coefficient. The magnitude of θ depends on the producer's packaging and the household's source reduction effort. We do not have any control over a firm's packaging effort and we focus on the household's source-reduction effort and its impact.

The technology of household recycling is given as:

$$r = R\left(g, T_s\right); R_g > 0, R_{T_s} > 0 \quad (5)$$

where r is the quantity of recyclables. Given an effort for household recycling, the quantity of recyclables increases as the total waste generation increases. Given a stock of total solid waste, the quantity of recyclable waste increases as the effort of recycling increases.

Combining all constraints, we get the total budget constraint:

$$M = wT + N = X - pr + K + wT_c + wT_S \quad (6)$$

where M is the full income. With the given utility function and the budget constraint, households maximize the utility with respect to *X*, T_c *and* T_s. The corresponding lagrangian is given as:

$$L = U\left(X, T_c, T_s\right) + \lambda\left(M - X + pr - K - wT_c - wT_S\right) \quad (7)$$

After solving the utility maximization problem given above, we derive the optimal solutions for demand functions T_s as follows:

$$T_s^* = T_s\left(N, K, p, w, \theta\right)$$

Based on the above solutions, the total waste generation and the recyclable supply are derived from constraints (4) and (5). Hence, the optimal demand for waste collection service and recycling service is given as:

$$r^* = R\left(N, K, p, w, \theta, g\right) \quad (8)$$

$$g^* = R\left(N, K, p, w, \theta\right) \quad (9)$$

Empirical Model

To represent the relationship between recycling and total waste generation, we use a system of structural equations given in equations (8) and (9). Based on the theoretical model outlined above, people's recycling behavior depends on exogenous variables such as non-labor income and fixed monthly waste collection fee. The total waste generation is an endogenous variable that determines people's recycling effort and behavior.

The dependent variable is a dummy variable which equals 1 if a representative household sells recyclable waste to a scrap dealer and 0 otherwise. Such an act is a proxy to one's informal recycling behavior. The price received from selling the recyclable waste should encourage people to recycle more (and we expect a positive sign for this variable). Unlike a unit-based pricing system, a conventional pricing system (which is independent of the weight or volume of waste) does not incentivize people to recycle more. Hence, we expect that a change in the monthly fee may not have any significant impact on people's recycling behavior. We use monthly income (instead of wage) to represent the effect of labor income on people's recycling behavior. Income represents opportunity cost of time, i.e., higher income people are expected to recycle less. The reaction function of recyclable supply includes household characteristicsA, and the recyclable supply function is given as:

$$r^* = R\left(N, K, p, w, \theta, g; A\right) \quad (8')$$

As given below, equations 9 and 10 represent the simultaneous equation model, where a household's recycling behavior depends on the total waste generation and the total waste generation depends on income, family size, and fixed waste collection fee. The total waste generation is represented in log-linear form:

$$r = \alpha_0 + \alpha_1 lng + \alpha_2 p + \alpha_3 Rec_{provision} + \alpha_4 soc_{capital} + \alpha_5 attitude + \alpha_6 A + \varepsilon \, (10)$$

$$lng = \beta_0 + \beta_1 lnIncome + \beta_2 Family_{size} + \beta_2 Fee + v \quad (11)$$

where *lng* represents log of total waste generation, and p is the price received from selling recyclable waste. As given in equation (10), factors that encourage recycling (r) are the recycling provision variables ($Rec_{provision}$) such as waste collection frequency, institutional regulation and distance from one's household to the waste collection point. Social capital ($soc_{capital}$) is represented by variables that create public awareness regarding recycling, such as recycling information, and participation and membership in sanitation related organizations. Another important variable that impacts people's recycling behavior is people's attitude towards recycling and waste segregation. (We expect that α_1, α_3 and α_4 are positively related to people's recycling behavior.) As the dependent variable is a binary variable, we use a Probit model to estimate the effect of different variables on people's recycling behavior. We checked for endogeneity and found that the total waste generation does not endogenously determine recycling. Hence the simultaneous equation model is not used.

Data and Descriptive Statistics

This study uses primary data from a household survey conducted in Kathmandu Valley, Nepal in 2012. The target sample was 1200 households and enumerators were able to collect data from 1155 households, which represent a 96 percent response rate, in all five municipalities of the Kathmandu Valley. Enumerators asked survey questions to one adult household representative in each of 1155 households. In the sample design, wards (the smallest administrative unit in Nepal) in each municipality are randomly selected; and the number of households in each municipality is selected using the Probability Proportional to Size (PPS) sampling technique. Twenty households from each selected ward were approached for interview using the right-hand rule. The sample size of 1200 households produces a ±2.8% sampling error margin at a 95 percent confidence interval in the overall sample level [21].

The survey questionnaire was prepared based on information received through previous literature, and debriefings and focus--group discussions with Kathmandu valley residents. This study uses survey data on three sections- i.e., people's knowledge, attitude and behavior towards recycling, status-quo recycling services, and socio-economic information. The dependent variable represents Kathmandu Valley residents' informal recycling behavior, a dummy variable which equals 1 if a household sold recyclable waste to a scrap dealer during the six months prior to the interview date (i.e., June 2012), and 0 otherwise. We controlled for the fact that people had access to the scrap dealers and hawkers who buy recyclable waste. According to Table 1, about 51 percent of households recycle waste informally. An average household generates 5.8 kilograms of total waste per week. We analyze the causal relationship of household's recycling behavior around four key factors: recycling provision, social capital, complementary behavior, and attitude. Three variables that represent recycling provision are: institutional regulation, distance to waste disposal site (*Distance*), and waste collection frequency (*Frequency*). Variables that represent social capital are membership or participation in a sanitation or environment related organization (*Participation_Membership*), and access to recycling information (*Recycling_Inf*). Variables representing complimentary behavior to recycling are: using a vegetable garden (*Veg_Garden*), and practicing composting (*Compost*).

Table 1: Descriptive Statistics of the Variables of Interest

Variable	Definition	Mean	Std. Dev.	Min	Max
recycle	Dummy for household's recycling behavior - 1 if household recycles, 0 otherwise.	0.51	0.5	0	1
totalwaste	Total waste generation per household per week in Kilogram.	5.8	4.14	1	50
Recycling Provisions					
Institutional Regulation	Institutional regulation - 1 if community has notice board about the rules of haphazard waste disposal, 0 otherwise.	0.48	0.5	0	1
distance	Walking distance in minutes from respondent's house to the waste collection point.	1.12	2.21	0	30
frequency	Frequency of waste collection per week.	4.12	3.7	0	21
Social Capital					
Participation_membership	1 if respondent or any other family member has participated in and is a member of environment and sanitation related organization, 0 otherwise.	0.29	0.45	0	1
recycling_inf	1 if respondent has access to information regarding recycling method, 0 otherwise.	0.87	0.34	0	1
Complimentary Behavior					
compost	1 if household practice composting, 0 otherwise	0.12	0.33	0	1
Veg_Garden	1 if respondent owns a vegetable garden at their residence, 0 otherwise	0.33	0.47	0	1
Attitude					
notlikeSeg	1 if respondent does not like to segregate waste, 0 otherwise	0.38	0.49	0	1
Control Variables					
above10thGrade	Dummy for respondent's education level, 1 if education above 10th grade, 0 otherwise	0.61	0.49	0	1
Monthly_Fee	Monthly Fee for solid waste collection service; fixed for units and varies over communities	56.39	88.61	0	600
age	Age of the respondent	35.97	13.41	18	86
income	Household's monthly income in Nepalese Rupees	34127.76	157646.7	1000	5000000
Familysize	Family size	4.73	2.15	0	21
Caste					
Janajati	Janajati	0.1	0.31	0	1

Brahman Chhetri	Brahman and Chhetri	0.34	0.47	0	1
Newar	Newar	0.5	0.5	0	1
MD_DT_other	Madheshi, Dalit and Other	0.05	0.22	0	1
N		1113			

We use a proxy variable for representing household's recycling behavior. If household sold recyclable waste within past six months of the interview date, recycle=1, 0 otherwise.

On average, people walk 1.12 minutes from their household to the waste collection point to dispose their waste, and the waste is collected 4.12 times per week. About 48 percent of households have municipality notice boards in their community that inform residents that they should not dispose waste haphazardly or else they will pay a certain fee as a penalty. This restriction imposes an institutional regulation regarding haphazard waste disposal. Social Capital is another important determinant of recycling as it imposes peer pressure and provides informal knowledge of recycling. About 29 percent of respondents have participated in or been a member of a sanitation related organization. About 87 percent of households have information regarding recycling and know how to recycle waste.

Composting is related to recycling and this study identifies how recycling and composting are related. Having a vegetable garden gives purpose and adds motivation to composting. About 33 percent of households in Kathmandu Valley have a vegetable garden and 12 percent of households practice composting. Lastly, attitudes towards recycling related activity also has a strong influence on recycling behavior. About 38 percent of households do not like segregating waste, which represents an attitude towards recycling. Households pay 56.39 Nepalese rupees (i.e., US$0.56) per month per household for the waste collection service.

Regarding the socio-economic characteristics of the households, the average household representative is 35 years old with an income of 34,127 Nepalese Rupees (i.e., US$340) per month. About 61 percent of respondents have an education above the tenth grade. Average family size is close to 5 members. About 50 percent of the respondents are from the Newar caste and 34 percent of respondents are Brahman and Chhetris.

Results

We estimate the factors influencing people's informal recycling behavior, and also identify the relationship between recycling behavior and the household's total waste generation. We use a Probit model to estimate the effect of several key factors on people's informal recycling behavior, which is the binary dependent variable. Table 2 presents the results of the Probit model that allow us to interpret the signs and significance of the variables; the marginal effects of these variables are presented in next table. Table 2 presents results in three models. Model 1 includes a waste generation variable and two key explanatory variables; Model 2 adds all the key explanatory variables; and Model 3 adds demographic variables. When the total waste generation increases, people tend to increase recycling, as indicated by a significant positive relationship of variable *log(totalWaste)* with recycling; this result is consistent with [11]. Four key factors determining recycling are: recycling provision, social capital, complementary behavior, and attitude.

Table 2: Probit Model for Household's Recycling Behavior

		Model 1		**Model 2**		**Model 3**	
	Dependent variable: *recycle*						
	Log(totalwaste)	0.256***	(3.73)	0.262***	(3.71)	0.220***	(2.89)
Recycling Provision	*Institutional Regulation*	0.226***	(2.76)	0.253***	(3.04)	0.213**	(2.48)
	distance	-0.0453**	(-2.46)	-0.0447**	(-2.42)	-0.0389**	(-2.03)

	frequency	-0.0111	(-1.06)	-0.00672	(-0.64)	-0.00549	(-0.48)
Social Capital	*participation_membership*	0.287***	(3.17)	0.268***	(2.94)	0.157[a]	(1.64)
	recycling_inf	0.337***	(2.79)	0.284**	(2.25)	0.188	(1.48)
Complement behavior	*compost*			0.332***	(2.82)	0.321***	(2.59)
	Veg_Garden			0.127[a]	(1.64)	0.134*	(1.65)
Attitude	*notlikeSeg*			-0.156**	(-2.02)	-0.142*	(-1.81)
	above10th Grade					0.303***	(2.99)
	Monthly_Fee/100					-0.00528	(-0.10)
	age					0.00219	(0.14)
	Age^2					-0.00011	(-0.61)
	income/10000					0.0598*	(1.65)
	(income/10000)^2					-0.00205	(-1.26)
	Reference Caste: *Janajati*						
	Brahman Chhetri					-0.174	(-1.21)
	Newar					-0.0858	(-0.58)
	Madheshi, Dalit and Other					-0.482**	(-2.13)
	_cons	-0.771***	(-4.54)	-0.781***	(-4.47)	-0.712**	(-2.03)
	N	1113		1113		1113	
	log_likelihood	-740.9		-732.3		-715.2	
	chi-squared	67.17		90.31		128.2	
	AIC	1495.8		1484.6		1468.3	

*p<0.1 ** p<0.05 *** p<0.01

t-statistics in parentheses; a= significance at 10.1 %

Having better recycling provisions usually encourages people to recycle more. For example, municipalities enforcing institutional regulations by announcing rules and penalties for haphazard waste disposal not only helps to avoid haphazard waste disposal but also increases recycling. As shown in Table 2, institutional regulation has a consistently positive effect on recycling through Models 1 to 3. As a spillover effect of institutional regulations, people sell more recyclable waste, and hence recycling acts as an alternative to disposing waste haphazardly. Having to walk longer distances from one's house to the waste disposal site discourages people to recycle, as it creates an inconvenience in walking long distances with multiple bags of segregated waste and increases the opportunity cost of walking time. Frequency of collection, however, does not have a significant effect on a household's recycling behavior. Municipalities collect household waste without keeping recyclable waste separate, which may demotivate people to segregate and recycle waste. Hence, waste collection frequency does not influence people's recycling behavior. Selling the recyclable waste to scrap dealers is people's personal decision.

We use people's attitude towards segregation as a tool to test their attitude towards recycling. People with positive (negative) attitude towards segregation practice recycling more (less). In other words, having a negative attitude towards waste segregation negatively affects people's recycling behavior. This result is consistent with the findings of [24]. The authors find that Malaysian people with a positive attitude towards recycling are 3.4 times more likely to recycle that those with a negative attitude.

The social capital of having membership in sanitation related organizations has consistently had a significant positive effect on recycling through Models 1 to 3. The knowledge of recycling (*Recycling_Inf*) significantly increases recycling in Models 1 and 2. In Model 3, after accounting for people's demographic characteristics, the effect is not significant. Zen et al. (2014) also found that most of the recyclers in Malaysia have very good knowledge of recycling.

People who compost are significantly more likely to recycle as well. People with a vegetable garden (*Veg_Garden*) are more likely to recycle than those without it. People with above tenth grade education are more likely to recycle, as they have a greater understanding of the environmental benefits of recycling. A fixed monthly fee (irrespective of weight or volume of the waste) does not provide a price incentive for recycling, unlike unit-based pricing. Therefore, a monthly fee for waste collection (*Monthly_Fee*) does not have any effect on the recycling behavior of Kathmandu Valley residents. Respondents' ages also do not have any effect on a household's recycling behavior. Household income has a significantly positive relationship with a household's recycling behavior, but the magnitude is small. Income has a non-linear effect; initially, up to a certain income recycling increases, but after a turning point recycling decreases with increasing income. We observe an opportunity cost of time, i.e., with increasing income people are less likely to recycle. Brahman Chhetri, Newar and Janajati castes are more likely to recycle waste in comparison to the caste groups who have faced discrimination in the past, i.e., Madheshi, Dalit, and other lower caste groups.

Table 3 presents the marginal effect of factors influencing a household's recycling behavior. According to the results, when a household generates 1 kilogram more waste per week, they are likely to increase recycling by 8 to 9.8 percent, depending on different controlling factors in Models 1 to 3. While controlling for different demographic variables in Model 2 and 3, the effect of waste generation remains consistently significant. Having an institutional regulation that controls haphazard waste disposal increases the probability of household recycling by 7.8 to 9.5 percent. People dislike walking long distances to dispose of their household waste, and this has a negative effect on their recycling behavior. With each additional minute an individual walks to dispose of household waste, his/her probability of recycling decreases by 1.4 to 1.7 percent. Social capital plays a significant positive role in increasing recycling; if a respondent or anyone in the family is a member of a sanitation related organization, they are 5.7 to 10.9 percent more likely to recycle. We have seen similar and even stronger impacts of social capital on informal recycling. For example, [23] in a study in Nigeria, has observed stronger social capital leading to a more systematic and regulated informal recycling system, and such social capital can be seen at household, community, city and intercity levels.

Table 3: Marginal Effect of the Probit Model for Household's Recycling Behavior

		Model 1		Model 2		Model 3	
	Dependent variable: *recycle*						
	Log(totalwaste)	0.0976***	(3.788)	0.0988***	(3.761)	0.0810***	(2.908)
Recycling Provision	Institutional Regulation	0.0864***	(2.790)	0.0952***	(3.076)	0.0784**	(2.495)
	distance	-0.0173**	(-2.474)	-0.0169**	(-2.436)	-0.0143**	(-2.041)
	frequency	-0.00424	(-1.066)	-0.00253	(-0.641)	-0.00202	(-0.484)
Social Capital	participation_membership	0.109***	(3.218)	0.101***	(2.973)	0.0577[a]	(1.643)
	recycling_inf	0.129***	(2.817)	0.107**	(2.268)	0.0692	(1.484)
Complement behavior	compost			0.125***	(2.837)	0.118***	(2.603)
	Veg_Garden			0.0480*	(1.651)	0.0494*	(1.652)
Attitude	notlikeSeg			-0.0588**	(-2.031)	-0.0522*	(-1.819)
	above10th Grade					0.111***	(3.017)

	Monthly_Fee/100					-0.00194	(-0.0978)
	age					-0.00209	(-1.427)
	income/10000					0.0178[a]	(1.640)
	(income/10000)^2					-0.00205	(-1.26)
	Reference Caste: *Janajati*						
	Brahman Chhetri					-0.0638	(-1.216)
	Newar						
	Madheshi, Dalit and Other					-0.0315	(-0.576)
	Observations	1,113		1,113		1,113	

* p<0.1 ** p<0.05 *** p<0.01; t-statistics in parenthesis; a= significance at 10.1 %

If a household composts biodegradable household waste, their probability of recycling is 11.8 to 12.5 percent more than those who do not compost. Hence, composting is a complimentary behavior to recycling in the Kathmandu Valley. This finding provides an important policy implication, namely, the promotion of recycling by bundling it with composting. People who own vegetable garden are 4.8 to 4.9 percent more likely to recycle in comparison to those who do not. Having a negative attitude towards waste segregation reduces recycling. People who dislike waste segregation are 5.2 to 5.8 percent less likely to recycle in comparison to those who like to segregate waste. Higher educated people also recycle more waste, which signifies the positive effect of knowledge and environmental awareness that induces them to recycle more. People with more than a tenth grade education are 11.1 percent more likely to recycle than those with below a tenth grade education. Unexpectedly and surprisingly, an individual's membership in or affiliation with a specific caste has a significant impact on their recycling behavior. In comparison to Madheshi, Dalit and other lower caste groups, Brahman Chhetris are 11.3 percent more likely to recycle, Newars are 14.6 percent more likely to recycle, and Janajati are 17.7 percent more likely to recycle.

According to the Wald test conducted in Table 4, there is no endogeneity in the model and hence the IV-Probit model is not required. However, we ran the IV-Probit model, with *total_waste* as the endogenous variable, and income, household size and monthly waste collection fee as the instrument variables, to test for the Wald test of exogeneity. Table 4 can be used for reference, although the results are not discussed in this paper.

Table 4: IV-Probit Model for Household's Recycling Behavior

	Model 1		**Model 2**		**Model 3**	
Dependent variable: *Recycle*						
Log(totalwaste)	0.519***	(2.91)	0.482***	(2.66)	0.674**	(1.97)
Institutional Regulation	0.177**	(2.15)	0.211**	(2.51)	0.151	(1.56)
distance	-0.0444**	(-2.46)	-0.0442**	(-2.42)	-0.0457**	(-2.37)
frequency	-0.0113	(-1.08)	-0.00716	(-0.68)	-0.00889	(-0.78)
participation_membership	0.274***	(2.99)	0.258***	(2.79)	0.143	(1.45)
recycling_inf	0.317***	(2.67)	0.270**	(2.18)	0.184	(1.50)
Veg_Garden			0.106	(1.35)	0.118	(1.42)
compost			0.353***	(3.04)	0.371***	(2.99)
notlikeSeg			-0.154**	(-1.99)	-0.134*	(-1.68)

Above10th Grade					0.259**	(2.32)
Monthly_Fee/100					-0.0463	(-0.77)
age					-0.00812	(-0.47)
Age^2					0.000000355	(0.00)
Income/10000					0.006295	(0.12)
(income/10000)^2					-7.22e-12	(-0.57)
Reference Caste: *Janajati*						
Brahman Chhetri					-0.196	(-1.39)
Newar					-0.0961	(-0.65)
Madheshi, Dalit and Others					-0.502**	(-2.34)
_cons	-1.146***	(-3.87)	-1.092***	(-3.62)	-1.477***	(-3.50)
athrho	-0.162	(-1.56)	-0.134	(-1.29)	-0.244	(-1.26)
lnsigma	-0.690***	(-22.93)	-0.693***	(-23.13)	-0.712***	(-23.86)
N	1113		1113		1113	
log_likelihood	-1550.6		-1539.1		-1501.3	
chi-squared	59.32		81.09		142.7	
AIC	3137.1		3126.2		3080.6	
Wald test of Exogeneity (/athrho = 0)						
athrho	-0.162	(-1.56)	-0.134	(-1.29)	-0.244	(-1.26)
chi2(1)		2.45		1.65		1.6

* p<0.1 ** p<0.05 *** p<0.01

t-statistics in parentheses; Log(totalwaste) is the endogenous variable; family size, income and waste collection fee are the instrument variables.

Discussion and Conclusion

Waste reduction at the source of generation is a sustainable way of managing waste in cities in developing countries. The standard three methods of minimizing waste are: reduce, re-use, and recycle. In the Kathmandu valley, people practice informal recycling by selling the recyclable waste to the scrap dealers. Some households also re-use some of the recyclable waste, such as plastic bottles and bins. Some households, however, burn paper and plastic in their back yards, which emits carcinogenic gas and pose threats to public health. Recycling is a safe way to minimize waste and maximize the estimated life of the landfill site. In the past, many landfill sites filled up much earlier than their estimated life and finding an alternative landfill site became a challenge to Kathmandu Valley municipalities, as people did not want a landfill site near their residence, also known as the 'Not in My Backyard (N-IMBY)' attitude.

This study uses a theoretical model based on the household production function to represent the Kathmandu Valley's informal recycling and conventional pricing for a waste collection system (i.e., a fixed fee for waste collection, irrespective of weight or volume of waste). The theoretical model incorporates the monetary benefits people receive from selling their recyclable waste. We expect that the price received from selling recyclable waste can be a significant incentive to promote recycling, and this provides an important policy implication. However, the limitation comes with the lack of data; we do not have data on prices received from selling recyclable waste. The majority of the existing literature identifies unit-based pricing as an important incentive to promote recycling [17, 18]. This study does not find any significant effect of pricing because of a fixed fee for waste collection.

Previous studies found an interdependence between total waste generation and recycling; people's recycling effort is modeled as an endogenous as well as exogenous variable. We accounted for such a possible interrelationship in the theoretical model. Our estimation and the Wald test of exogeneity proved that total waste generation does not endogenously determine recycling, and hence the results are estimated using a Probit model, rather than IV-Probit. The relationship between total waste generation and recycling is significantly positive. People who generate more waste are more likely to recycle; this result is consistent with the findings of [11]. [11] also found that when households' recycling rate increases, total waste generation increases, as the households reduce their waste reduction effort at the source.

According to the findings, the important factors that positively influence households' recycling behavior are people's knowledge of recycling, positive peer pressure through social capital, institutional regulation, complementary behaviors to recycling such as composting, and positive attitude towards waste segregation. Our findings are somewhat similar to that of the theory of planned behavior, even though we do not apply this theory in building the theoretical model of this study.

As a policy implication based on the findings, municipalities can implement and enforce institutional regulations, as this not only avoids haphazard waste disposal but also increases recycling. Local authorities can take initiative to establish sanitation and environment related organizations at community level, and involve more people in such organizations. Composting is a complementary behavior to recycling, as people who compost are significantly more likely to recycle. Currently, municipalities are promoting household composting by providing composting bins at a subsidized price. Municipalities can promote recycling by bundling it with composting. Increasing public awareness regarding recycling methods can also boost recycling; as having access to recycling information significantly increases the recycling rate. These findings and policy implications can be applied to growing cities in other developing countries as well.

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