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(Research Article)

The competitiveness of recycled products and the recovery of secondary raw materials from Municipal Solid Waste (MSW) in Antsirabe

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Abstract

In Antsirabe (Madagascar), secondary raw materials are abundant but underutilised. The market value of secondary raw materials depends indirectly on the demand for recycled end products, which is itself influenced by their competitiveness (price and quality) compared with products made from virgin materials. This study aims to determine, for each category of recycled product, the optimal level of competitiveness (relative price and perceived quality) that maximises local demand. A cross-sectional survey was conducted amongst 450 consumers, retailers and recyclers in Antsirabe. Four product categories were analysed (plastic clothes pegs, aluminium cooking pots, recycled construction steel, and compost). A quadratic regression model, estimated using ordinary least squares, was used for each category, with a composite competitiveness index as the explanatory variable and income as the control variable.

The results confirm a non-linear relationship in the shape of an inverted U. The optimal competitiveness indices are: 2.14 for clothes pegs (R^2 = 0.57), 1.57 for saucepans (R^2 = 0.93), 2.00 for construction rebar (R^2 = 0.59) and 3.41 for compost (R^2 = 0.99). The revenue variable is significant only for compost. Each category of recycled product has a specific competitiveness optimum that maximises its demand. These results provide operational targets for recyclers and public decision-makers to enhance the recovery of secondary raw materials in Antsirabe.

Keywords: Recycled products; Competitiveness; Demand; Municipal solid waste; Antsirabe; Madagascar

1. Introduction

The market value of municipal solid waste (MSW) depends primarily on the secondary raw materials (SRMs) it contains, as well as the economic opportunities associated with its recovery. This value is positive when the (anticipated) cost of waste treatment is lower than the (anticipated) revenue from recovery [1]; however, current technological limitations result in a significant loss of value for certain recyclable materials, such as plastic (nearly 75 per cent of their value), after their first use [2].

Globally, the transition from a linear to a circular economy is intensifying competition between recycled and virgin finished products, affecting the respective demand and prices of recycled materials (MPS) and virgin raw materials (MPV) [3]. Due to the substitution effect, for example, the presence of recycled material drives down the price of virgin products [4]. Despite the significant environmental pressures arising from the extraction of VPMs [5], as well as the oversupply of virgin materials on global markets (e.g. virgin plastic), which is narrowing the gap with recycled materials, the consistency and reliability of virgin products give them a premium image [3], whilst the intention to purchase recycled finished products is influenced by several factors, such as perceived safety and a favourable image [6, 7, 8], attitude, attractiveness and the eco-friendliness of the packaging [9], and the availability of eco-labels [10]; however,

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the main determinant of consumer purchasing behaviour towards recycled products is perceived quality. When this is equivalent to or higher than that of virgin materials, the market share can reach up to 40 per cent in certain segments such as textiles and plastics [11].

In the African region in general, and the Indian Ocean in particular, the post-consumer recycled materials market is experiencing significant growth, but also price volatility and competition from virgin materials [12]. Due to falling operating costs (e.g. for hydrocarbons) and economies of scale among virgin material producers, certain recycled materials such as recycled plastics (e.g. PET and HDPE) are sold at prices lower than those of virgin plastics. This situation, exacerbated by varying perceptions of the quality of recycled end products – which acts as a major barrier to demand – is affecting the market value of MPS, despite growing demand for sustainable packaging and products in several countries across the region [13, 14].

In Madagascar, the majority of MPS processing is carried out on a small-scale, artisanal basis; only around 10 per cent of post-consumer waste is recovered in the form of recycled plastics or compost [15]. Due to weak industrial demand and the lack of standardised specifications for recycled products, coupled with increased competition from imported virgin materials—which are considered more uniform and reliable—the market value of local post-consumer plastics is generally lower than the costs of processing them [16, 15].

In Antsirabe, the processing of solid waste, although abundant, remains largely carried out by informal waste collectors, peri-urban farmers and artisans who recycle solid waste into various products, notably interlocking paving stones and clothes pegs (for plastics), compost (for biomass), or other handicrafts to be sold on the local market. As for metals, they sell them directly to scrap dealers or resellers [15]. There is demand for recycled finished products, but it is mainly concentrated in the artisanal sector and influenced by a negative perception of quality compared to virgin products [14], which in turn affects the prices of secondary raw materials. The aim of this article is to analyse the influence of the competitiveness of recycled products on the formation of the market value of secondary raw materials. In the absence of comprehensive data on secondary raw material prices—which stems mainly from the still informal nature of marketing channels, price variability depending on market participants and volumes traded, as well as the lack of structured statistical databases— this study employs the derived demand approach, positing that variations in the market value of secondary raw materials are primarily explained by the demand for the recycled products derived from them, which is itself influenced by their relative competitiveness compared with virgin products. This raises the question: what is the optimal level of competitiveness (the relationship between relative price and perceived quality) that maximises demand for each category of recycled end products in Antsirabe? In response to this question: for each category of recycled product, there is a specific optimal level of competitiveness. Below and above this threshold, demand is lower (an inverted U-shaped relationship).

2. Methods

2.1. Study area

The study was conducted in the urban municipality of Antsirabe, situated in the Vakinankaratra region, in the Central Highlands of Madagascar. Its geographical coordinates are 19°50’ south latitude and 47°02’ east longitude. The municipality covers an area of approximately 180 km², at an average altitude of 1,500 m.

The climate is of the highland tropical type (Cwb according to the Köppen classification), characterised by an average annual temperature of 18.5 °C (ranging from 9 °C to 26 °C) and an average annual rainfall of 1,200 mm, concentrated over two rainy seasons (November to April). Land use is distributed as follows: urban areas (45 per cent), agricultural land (35 per cent) and wetlands (20 per cent). The population is estimated at 265,000, of whom around 70 per cent are engaged in informal activities (trade, crafts, small-scale farming).

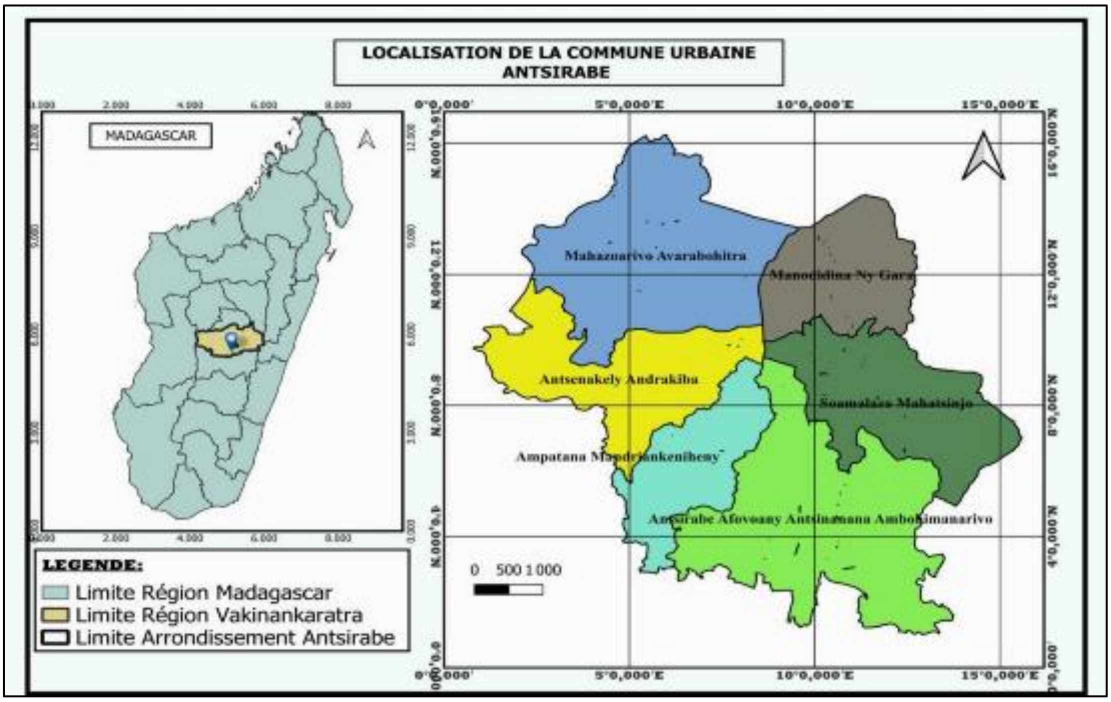

Figure 1 Map showing the location of the study area

2.2. Data collection and processing methods

To carry out this research, and in order to take into account the specific characteristics of each market segment, the analysis was conducted by category of recycled products. A list of recycled products available on the local market was drawn up based on similar virgin finished products (same unit of measurement, for example: recycled and virgin saucepans of the same capacity) s that are direct competitors, as well as the corresponding MPS. This list is presented in Table 1 below:

Table 1 List of recycled products compared with directly competing virgin end products on the local market and the corresponding MPS.

Virgin finished products	Recycled finished products	Corresponding MPS
Clothes pegs	Clothes pegs	Plastic
Imported structural steel bars	Locally manufactured construction rebar	Scrap iron
Imported aluminium pots.	Locally manufactured aluminium pots.	Aluminium
Chemical fertilisers	Compost	Organic

2.2.1. Units of observation

The study is based primarily on cross-sectional primary data, collected from samples by type of stakeholder involved in the waste recovery chain: end consumers (to measure the quantities purchased as well as perceptions of the price and quality of recycled products), retailers (to estimate the volumes actually sold on the market) and recyclers or producers (to assess the quantities produced and the conditions under which they are placed on the market).

2.2.2. Sampling

Given the lack of a formal register for the recycled products market, a preliminary phase to identify market participants was carried out in order to establish an operational sampling frame. The twostage, multi-stakeholder stratified sampling method adopted captures the structural heterogeneity of the local market. In the case of clothes pegs, buyers were selected by systematic on-site sampling, sellers by simple random sampling from a pre-existing list, and recyclers were subject to an exhaustive census. Due to the geographical dispersion of compost users, a two-stage cluster sampling method was adopted. Peri-urban agricultural areas constituted the primary sampling units, within which farms using compost were selected by random sampling. The recycled iron market is characterised by the presence of a single supplier located outside the study area. Consequently, supply was considered exogenous and the econometric analysis focused on the behaviour of local demand. To account for the sporadic nature of pot purchases, the sampling was not based on a random selection of households, but on a flow survey conducted directly at the main points of sale in Antsirabe (Asabotsy market, Antsenakely and artisanal sales outlets).

The breakdown of the sample by product is shown in Table 2 below:

Table 2 Breakdown of the sample

Product / Stakeholder	Buyers	Sellers	Recyclers	Farmers	Total
Clothes peg	100	30	5		135
Saucepan	100	30	4		134
Iron	100	30	1		131
Compost	-	-	-	50	50

There are a total of 450 observations

2.2.3. Competitiveness

The competitiveness of recycled products was assessed using a composite index combining relative price and relative quality, as shown in equation (1):

$COMPi, = w1 \times PRi, + w2 \times Qrel,,$ (1)

Where:

w_1 andw_2 are weighting coefficients such that $w_1 + w_2 = 1$; as no prior empirical data is available, equal weighting ($w_1 = w_2 = 0{,}5$) has been adopted in order to give equal importance to price and quality.

$PR_,$: Relative price of observation unit i for category c

$Q_{rel,,}$: Relative quality of observation unit i for category c, obtained by comparing the perceived quality of recycled products with that of virgin products (Demets et al., 2021).

Relative prices of recycled and virgin finished products

The relative price is the ratio of the price of a recycled product to that of an equivalent virgin product. To determine this, the following equation (2) (*Mankiw, 2025*) was used:

$$Prix\ relatif\ (PR) = \frac{Prix\ du\ produit\ finis\ vierge}{Prix\ du\ produit\ finis\ recyclé} \quad (2)$$

Relative price< 1: the recycled product is more expensive than the virgin product;

Relative price = 1: both products have the same price;

Relative price> 1: the recycled product is cheaper than the virgin product.

Relative prices were collected through observation, specifying the type of product, its nature (recycled or virgin), and its unit price, by systematically recording retail prices on the local market and from a stratified sample of retailers.

The perceived quality (PQ) of recycled products

Perceived quality is the consumer's judgement of a product's overall excellence or superiority [17]. To measure this, a survey was conducted amongst a reasoned and stratified sample of consumers using each type of recycled product, using a structured questionnaire administered indirectly, comprising:

A 3-point Likert scale (1 = poor, 2 = average, 3 = good); Table 3 shows the evaluation criteria associated with each product.

A comparative question asking respondents to assess whether a given recycled product is considered to be of better, equal or lower quality than an equivalent virgin product;

Open-ended questions to assess the reasons behind the ratings.

Table 3 Criteria for assessing perceived quality

Products	**Compost**	**Clothes peg**	**Iron**	**Cooking pots**
Criteria assessing perceived quality.	Smell	Holding strength	Mechanical strength	Strength
	Apparent fertilising power	Durability	Dimensional stability	Firing performance
	Absence of contaminants	Ergonomics	Weldability	Ergonomics
	Ease of use	Aesthetics	Durability	Safety and hygiene
	Value for money	Value for money	Value for money	Value for money

The average scores for each evaluation criterion relating to the perceived quality of each recycled and virgin product were calculated in order to obtain the overall perceived quality score from equation (2), as follows:

$$Score\ global = \frac{Somme\ des\ scores\ individuels}{5} \quad (2)$$

2.2.4. Local demand for recycled finished products

The demand, denoted by $DPR_{i,}$, corresponds to the quantity of recycled product purchased, sold or produced by observation unit i, for category c, over a reference period (1 year). The estimation of the demand function is based exclusively on data from buyers. The information collected from sellers and recyclers was used to validate the price and quality variables, as well as to characterise supply conditions in the market.

For saucepans, as durable goods, conventional demand is replaced by Purchase Intention (PI), measured on a probability scale (Juster scale from 0 to 10). This method makes it possible to quantify potential demand subject to a change in price or quality. To minimise subjective bias, the survey uses Willingness to Pay (WTP), characterised by:

- Observation: physical presentation of the recycled product and the virgin product.
- Evaluation: rating of quality criteria (durability, cooking performance, safety).
- Decision-making: determining the maximum acceptable price for the recycled product, taking into account its perceived quality.

For compost, although it is not a durable good in the same sense as cooking pots, the absence of a structured market in Antsirabe also necessitates an approach based on potential demand.

2.2.5. Income level or purchasing power

Certain socio-economic characteristics likely to influence demand are incorporated as a control variable, denoted by Z, and we have chosen income level or purchasing power (presented on a scale according to occupation, from 1: low, 2: medium, 3: intermediate, 4: high), which aims to reduce omission biases in the econometric estimation.

2.3. Data analysis methods

The econometric analyses were carried out using the R software (version 4.3.2), utilising the lm() function from the stats package. The standard assumptions of OLS (normality of residuals, homoscedasticity, absence of multicollinearity) were tested using the Shapiro-Wilk and BreuschPagan tests, and the variance inflation factor (VIF), respectively.

2.3.1. Specification of the econometric analysis model

For each category of recycled product, the relationship between competitiveness and demand is modelled by a quadratic demand function, given by the following equation (3):

$$DPR_{i,c} = \beta_0 + \beta_1 . COMP_{i,c} + \beta_2 . COMP_{i,c}^2 + \gamma Z_{i,c} + \varepsilon_{i,c} \qquad (3)$$

Where:

β_0 : is a constant;

β_1 and β_2 : measure the linear and saturation effects of competitiveness, respectively;

γ : corresponds to the coefficients of the control variables $Z_{i,}$;

$\varepsilon_{i,c}$: is the error term.

The quadratic form of demand was chosen for the model as it allows an optimal level of competitiveness to be identified.

2.3.2. Verification of the model's reliability

Three tests were carried out to verify the reliability of the model:

The significance of each coefficient was assessed using the t-test, to ensure that competitiveness and the control variables do indeed influence demand;

The overall suitability of the model was tested using the F-test;

The proportion of the variance in demand explained by the model was measured using the coefficient of determination R^2 .

2.3.3. The optimal level of competitiveness

Once all the conditions relating to OLS estimation and the verification of the model's reliability have been met, the estimated coefficients can be used to calculate an optimal level of competitiveness using equation (4), as follows:

$$COMP^* = -\frac{\hat{\beta}_1}{2\hat{\beta}_2} \qquad (4)$$

3. Results

3.1. Model specification for clothes pegs

3.1.1. Robustness and overall validity of the model

Table 4 Regression statistics

Indicator	Value
Observations (N)	100
R^2	0.573
Adjusted R^2	0.56
Standard error of the residuals	8.439 (df = 96)
F-statistic	43.008*** (df = 3; 96)

Statistical tests confirm the reliability of the model: it explains 57.3% of the demands ($R^2 = 0.573$) with very high overall significance ($F = 43.00$; $p < 0.001$).

3.1.2. Regression coefficient estimates

Table 5 Model parameters

Variable	Coefficient	95% CI	t	P
Constant (β_0)	7.19	[11; 25.38]	0.78	0.435
COMP	48.83	[36.11; 61.54]	7.62	< 0.001
COMP^2	-11.4	[-13.89; -8.92]	-9.12	< 0.001
Income (Z)	-0.13	[-4.01; 3.74]	-0.07	0.946

The results in Table 5 indicate that the demand for clothes pegs is significantly influenced by the competitiveness index, with a positive linear effect (β_1 = 48.83) and a negative quadratic effect (β_2 = -11.40). The income variable is not statistically significant (p = 0.946), which establishes the demand function as follows:

DPR = 7.19 + 48.83 COMP - 11.40 COMP^2

3.1.3. Optimal level of competitiveness for recycled clothes pegs

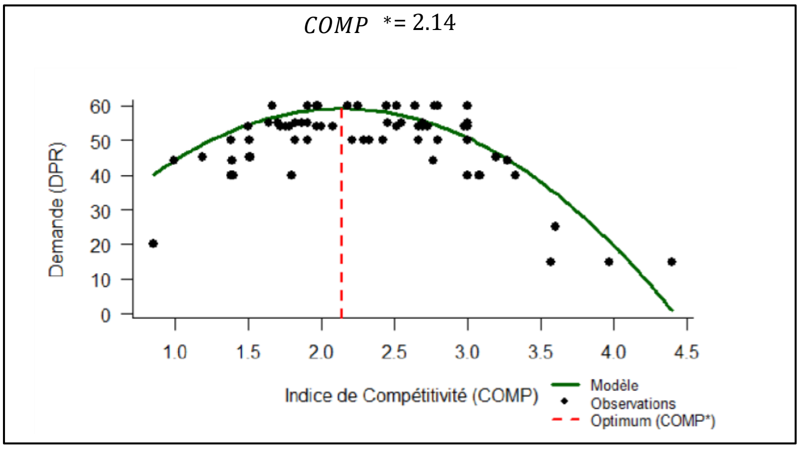

Figure 2 Demand for recycled clothes pegs

The optimum of 2.14 represents the peak of the demand curve, where market penetration reaches its maximum of 57.3%.

3.2. Model specification for aluminium cooking pots

3.2.1. Robustness and overall validity of the model

Table 6 Regression statistics

Indicators	Values
Observations (N)	100
R^2	0.934
Adjusted R^2	0.932
Standard error of the residuals	0.5 (df = 96)
F-statistic	452.685*** (df = 3; 96)

According to Table 6, the competitiveness index explains 93.4% of purchase intentions (R^2 = 0.934). The analysis of variance confirms the statistical significance of this relationship, ruling out any random effects.

3.2.2. Regression coefficient estimates

Table 7 Model parameters

Variable	Coefficient	95% CI	t	P
Constant (β_0)	-19.79	[-21.91; -17.67]	-18.53	< 0.001
COMP	38.26	[35.03; 41.5]	23.5	< 0.001
$COMP^2$	-12.2	[-13.42; -10.99]	-19.98	< 0.001
Income (Z)	-0.1	[-0.33; 0.13]	-0.85	0.397

The results in Table 7 show that demand for pots depends on competitiveness: the positive linear effect (β_1 = 38.26) stimulates purchases, whilst the negative quadratic effect (β_2 = -12.20) confirms a saturation threshold. The fact that income is not statistically significant (p = 0.397) indicates that only the product matters, according to the equation:

$$DPR = -19.79 + 38.26\ COMP - 12.20\ COMP^2$$

3.2.3. Optimal level of competitiveness for recycled pots

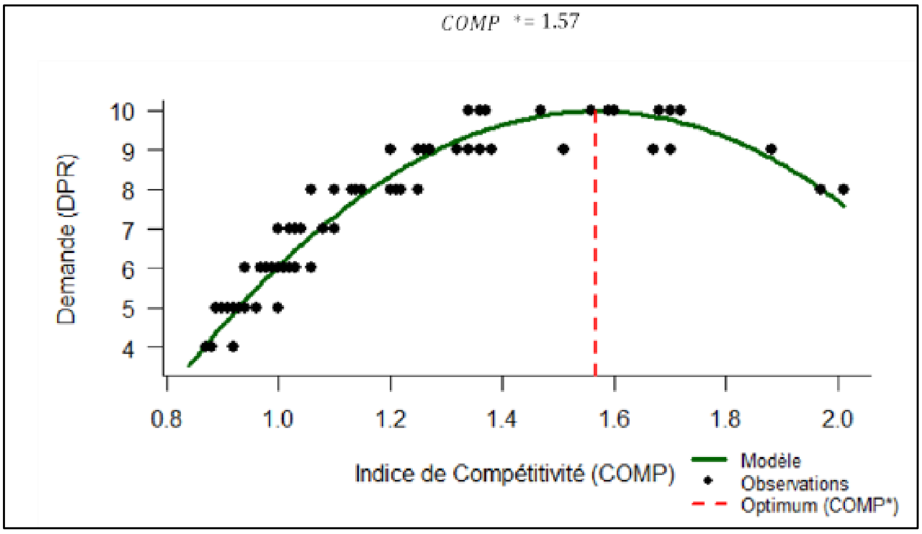

Figure 3 Demand for recycled pots

The optimum of 1.57 represents the peak of the demand curve, where market adherence reaches its maximum of 93.4%.

3.3. Model specification for construction steel

3.3.1. Robustness and overall validity of the model

Table 8 Regression statistics

Indicators	Values
Observations (N)	100
R^2	0.592
Adjusted R^2	0.58
Standard error of the residuals	1.2 (df = 96)
F-statistic	46.529*** (df = 3; 96)

Table 8 shows that the competitiveness index explains 59.2% of purchase intentions for construction steel ($R^2 = 0.592$). The extremely low F-statistic confirms that this model is statistically very robust and is not due to chance.

3.3.2. Regression coefficient estimates

Table 9 Model parameters

Variable	Coefficients	95% CI	t	p
Constant (β_0)	-30.7582	[-41.6087; -19.9077]	-5.6269	0
COMP	65.4957	[54.4652; 76.5262]	11.7862	0
$COMP^2$	-16.3459	[-19.0923; -13.5995]	-11.8142	0
Revenue (Z)	-0.1713	[-0.4116; 0.069]	-1.415	0.1603

Table 9 shows that demand for construction steel is based on technical factors: the positive linear effect ($\beta_1 = 65.50$) stimulates purchasing, whilst the negative quadratic effect ($\beta_2 = -16.35$) indicates that excessive competitiveness creates mistrust, leading to market saturation. As income has no significant influence ($p = 0.160$), the demand function is established as follows:

$DPR = -30.75 + 65.49\ COMP - 16.34\ COMP^2$.

3.3.3. Optimal level of competitiveness for construction steel

$COMP^* = 2.00$

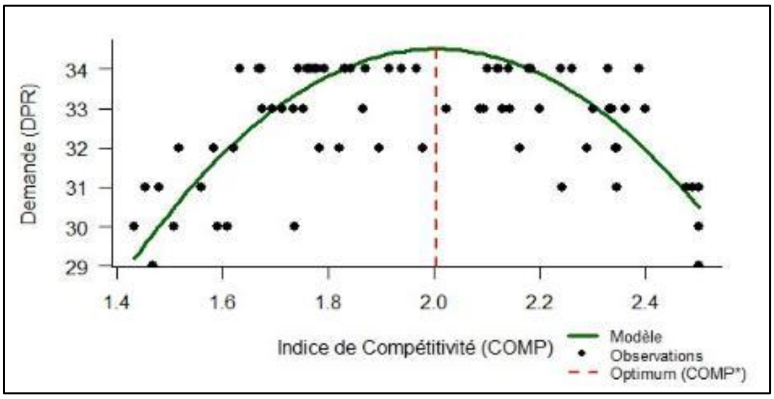

Figure 4 Demand for recycled construction steel

Figure 4 illustrates the trade-off between price and quality, identifying an optimal level of demand at a competitiveness index of 2.

3.4. Model specification for compost derived from DSM.

3.4.1. Robustness and overall validity of the model

Table 10 Regression statistics

Statistic	Value
Observations (N)	50
R^2	0.988
Adjusted R^2	0.987
Standard error of the residuals	2.9 (df = 46)
F-statistic	1241.535*** (df = 3; 46)

As shown in Table 10, the model has a coefficient of determination R^2 = 0.987, indicating that it explains 98.7% of the variance in demand for compost, with an F-statistic (1241.53) associated with a critical value of 5.29E-44, confirming the statistical validity of the regression.

3.4.2. Regression coefficient estimates

Table 11 Model parameters

Variable	Coefficients	IC_95%	t	p
Constant (β_0)	-20.442	[-42.4501; 1.5654]	-1.8697	0.0679
COMP	118.284	[106.967; 129.6015]	21.0381	< 0.0001
$COMP^2$	-17.332	[-18.7136; -15.9508]	-25.255	< 0.0001
Revenue (Z)	9.9016	[9.1204; 10.6828]	25.5129	< 0.0001

The results in Table 11 indicate that the demand for compost is influenced by the competitiveness index, with a positive linear effect (β_1 = 118.28) and a negative quadratic effect (β_2 = 17.33). The income variable (Z) is highly significant here (p = 8.56E-29), which defines the following demand function:

$DPR = -135.16 + 118.28\ COMP - 17.33\ COMP^2 + 0.10\ Z$

3.4.3. Optimal level of competitiveness for compost derived from DSM

$COMP^*$= 3,41

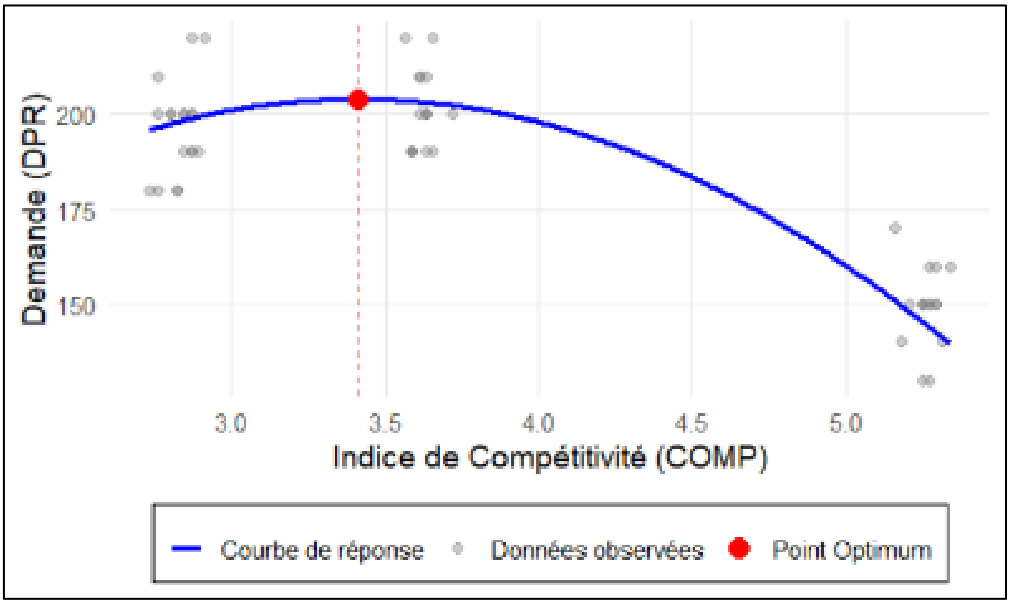

Figure 5 Demand for compost derived from MSW in Antsirabe

4. Discussions

Our results confirm that there is a 'break-even point' for the competitiveness of each recycled product: this is the level beyond which demand no longer increases, or eventually begins to fall.

4.1. Clothes pegs (plastic)

For this product, the only factor that matters is value for money; the buyer's social background has no influence (Table 5). Demand rises up to an index of 2.14 (Figure 2), which is the ideal level. Beyond this point, competitiveness taken to the extreme (with a price that is too low) works against the product: customers are wary of the quality. Whilst Magnier's (2022) research in *Consumer Acceptance of Recycled Plastics: The Role of Price and Quality Cues* shows that price and environmental considerations play a role, it overlooks the fact that, for consumers in Antsirabe, price is first and foremost a guarantee of durability. The value of these recycled items therefore depends on the technical confidence that the recycler manages to inspire.

4.2. Aluminium cooking pots

Here, the economic reality is stark: immediate needs take precedence over all else (Table 9). With a 93.4 per cent dependence on price, the market is constrained by a low index of 1.57 (Figure 3). Unlike the studies by Singh (2023) in *Beyond Green: The Dominance of Economic Factors in Recycled Product Purchase Intentions in Developing Markets*, which focus on psychological motivations, our study shows that in situations of financial insecurity, budget constraints impose an insurmountable barrier. The value of these products will remain stagnant until recyclers manage to reduce their manufacturing costs to make the product more affordable.

4.3. Recycled construction steel

When it comes to steel, the choice is a matter of safety. The optimum at 2.00 (Figure 4) reveals a paradox: if the price is too low, buyers worry about the structural integrity of their building. Whilst Densley-Tingley (2021) addresses the issue from the perspective of standards in *Safety Perceptions and Technical Trust in Reused Steel Components for Housing*, we demonstrate here the importance of price as a signal of safety. In Antsirabe, price takes the place of technical certification: to sell recycled steel, one must guarantee impeccable quality that reassures the builder about the durability of their home.

4.4. Composts derived from DSM

This is the product with the greatest potential. Its high optimum value of 3.41 (Figure 5) demonstrates that farmers are willing to pay for nutritional quality. However, one concern remains: that of hidden toxicity. Unlike the purely biological approaches outlined by Zurbrugg (2022) in *Logistics and Biological Optimisation of Municipal Solid Waste Composting in Sub-Saharan

Africa*, we show that the obstacle here is psychological and commercial. The value of compost depends not only on its chemical richness, but on the system's ability to guarantee total purity in order to protect the soil.

4.5. Limitations of the study

Although it provides important insights, this study has five main limitations. The cross-sectional nature of the 2025 data prevents the capture of seasonal variations, particularly for compost. The competitiveness index is based on a theoretical equal weighting (0.5), despite conclusive sensitivity analyses. Furthermore, the small sample size of recyclers (n=5 and n=4) limits the generalisability of the results regarding supply, whilst the self-reported measure of quality introduces a social desirability bias. Finally, as the study is based in Antsirabe, the external validity of these conclusions in light of the specific characteristics of other African urban centres remains an area to be explored.

5. Conclusion

The aim of this research was to determine the optimal level of competitiveness, balancing price and quality, in order to maximise demand for recycled products and thereby enhance the value of secondary raw materials (SRMs) in Antsirabe. Using a quadratic regression model, the analysis demonstrates that demand for these products does not follow a linear trajectory, but reaches equilibrium points where economic realities align with human perceptions. For clothes pegs, the optimum of 2.14 reveals that price acts as a signal of durability, whilst for cooking pots, the optimum of 1.57 highlights an inescapable dependence on subsistence constraints. Construction steel, with its optimum of 2.00, illustrates a safety paradox whereby a derisory price hinders adoption due to fears of collapse. Finally, compost stands out with the highest optimum (3.41), proving that nutritional performance is a powerful driver of value, albeit limited by persistent health-related mistrust.

These results confirm the initial hypothesis that there is an optimal equilibrium point specific to each product category. There is a strong alignment between the econometric e al evidence obtained and the study's findings: it validates the idea that the competitiveness of finished products is the fundamental lever for structuring the waste market in Madagascar. The study provides scientific evidence that waste recovery cannot be separated from psychological trade-offs and the economic dignity of households. In answering the initial research question, this conclusion establishes that the success of the circular economy in Antsirabe depends on recyclers' ability to position themselves precisely within these equilibrium segments in order to secure buyers' trust and, consequently, the profitability of collection.

Looking ahead, this research suggests two major avenues for future research: on the one hand, it appears necessary to explore technical innovation levers capable of reducing processing costs, particularly for aluminium, in order to loosen the stranglehold of the subsistence market that hinders the recovery of construction and demolition waste. Secondly, further studies on the standardisation and social certification of compost and recycled building materials could be carried out. The aim would be to test whether official certification could shift the optimal points upwards, by replacing simple price-based intuition with institutional trust, thereby paving the way for a more ambitious and people-centred recovery of resources from municipal solid waste.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

Statement of ethical approval

The study was conducted with the approval of the relevant academic and local authorities, ensuring adherence to ethical research standards.

Statement of informed consent

Informed consent was obtained from all individual participants included in this study, and all data were collected and processed confidentially for research purposes.

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