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**Spatial Disparity, Information, and the Economics of Cool Transportation**  
**Insights from a Randomized Controlled Trial in Nigeria**

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## Abstract

Food loss is a significant source of economic inefficiency in value chains. In many developing countries, including Nigeria, a majority of fruits, vegetables, and other perishable foods are lost after harvest, due in large part to inadequate postharvest handling or low adoption of post-harvest management technologies, particularly cooling technologies such as temperature-controlled transportation and cold storage. To examine the economic impacts of cool transportation connecting vegetable-producing states in northeast Nigeria to large demand centers in Nigeria's southern regions, we introduced a randomized controlled trial. Cool transportation was found to have a large and statistically significant impact: sales price, revenues, and profits increased substantially for the origin-state marketers. A larger portion of sales price increase at the destination market is attributed to refrigeration, that is, quality preservation through cooling. About 66 percent of this increase comes from cooling, with an additional 34 percent from transportation. An information experiment further showed that improved quality information through labelling that identifies the origin of the produce creates price premiums at the destination market. This implies that significant economic gains can be generated not only from narrowing supply–demand gaps in different markets but also, potentially, through mitigating spatial asymmetric information.

**Keywords:** Food loss, cool transportation, spatial disparity, asymmetric information, tomato, Nigeria

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## 1. INTRODUCTION

Food loss is a significant source of economic inefficiency in value chains. In many developing countries, including Nigeria, a majority of fruits, vegetables, and other perishable foods are lost after harvest, due in large part to inadequate postharvest handling or low adoption of post-harvest management technologies including drying, packaging, storage, and cooling technologies such as temperature-controlled transportation and cold storage (for example, FAO, 2011; Sheahan and Barrett, 2017). As a result, adequate availability of fresh fish, fruits, vegetables, milk, eggs, and meat as well as the safety and nutritional content of these foods, are affected (Schreinemachers et al., 2018; Allen and de Brauw, 2018). Under such conditions, all agents along the supply chain, including farmers, aggregators, food processors, and markets, suffer from income reduction, while consumers face unstable supply of fresh products and less nutritious, low-quality foods (Balana et al., 2022). High levels of food loss also pose serious burdens on natural resources (for example, Kashyap and Agarwal, 2020; Aragie, 2021). Inadequate development of value chains and barriers to effective practices and innovations, such as awareness and high costs, are primary drivers of food loss (Prusky, 2011; Plaisier et al., 2019; Stathers et al., 2020; Makule et al., 2022; Ricker-Gilbert et al., 2022; Rutta, 2022; Jarman et al., 2023; Mutungi et al., 2023; Stathers et al., 2025; Yami, et al., 2025; among others).<sup>1</sup>

In Nigeria, significant production shares of major food items—for example, onion (47 percent), tomato (38 percent), and cowpea (35 percent)—originate from the northern region of the country. Several local horticulture varieties can grow under rainfed conditions, and the growers possess knowledge of basic

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<sup>1</sup> For food loss measurements, see papers included in the special edition of *Food Policy*, vol.98, *Food Loss and Waste: Evidence for Effective Policies*, such as Delgado et al. (2021). Other works include Affognon et al. (2015) and Kaminski and Christiaensen (2014). For policy debates and knowledge gaps, see Cattaneo et al. (2021) included in the above special edition. Mayienga and Cachia (2021), Kok, M.G. et al. (2019), and Luo et al. (2021) discuss conceptual issues related to the measurement of food loss.

irrigation that enables dry-season horticulture production in the region. In contrast, demand is largely concentrated in the southern and central parts of the country, such as Lagos, Port Harcourt, and Abuja. Seasonal variations of horticultural production and spatial gaps in supply and demand result in a large amount of food loss in the economy (Van Den Broek et al., 2021). Generally, poor harvesting techniques, fragile packaging materials, lack of cold storage facilities, and weak transportation networks contribute to high levels of food loss.

Transportation plays a critical role in addressing spatial gaps in supply and demand.<sup>2</sup> However, temperature stress during travel may also cause losses in quantity and quality (for example, Sarah et al., 2025), as well as physical damage (for example, Al-Dairi et al., 2022), and these losses increase with both distance and time. Moreover, logistical decisions on destination cum route choice and timing should be made optimally in response to dynamically changing market conditions. To overcome these challenges, modern cooling technologies, that is, cool transportation, are essential.

Cool transportation technologies such as temperature-controlled trucks and cold storage facilities are crucial to combat spoilage of perishable vegetables and fruits in warm climates. The key comparative advantage of cool transportation is mobility, allowing businesses to connect distant markets to customers. Along the supply chain, cold storage acts as a static hub and provides a stable, fixed environment crucial for preserving product quality over time.<sup>3,4</sup> While cool transportation and cold storage can be

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<sup>2</sup> See Fafchamps and Shilpi (2003), Yamauchi et al. (2011), Yamauchi (2016), and Kaiser and Barstow (2022) on the roles of rural roads in economic behavior and outcomes.

<sup>3</sup> Recently, Takeshima et al. (2023) conducted an experiment to estimate 3-month impacts of solar powered cold storage. A follow-up study was conducted to re-estimate longer term impacts over 2 years (Takeshima et al., 2025), which proves that the impact confirmed in the 3-month study remained sustainable over 2 years. Yamauchi and Takeshima (2023) computed the internal rate of returns in solar powered cold storage, relative to grid and diesel generator powered cold storages. Solar powered cold storage stands as a viable option especially in the environment where electricity supply is unavailable or unstable.

<sup>4</sup> Minten et al. (2014) shows the case that cold storages turned out to be local hubs in which not only temperature control but also various inputs and services are provided.

complementary in the cold chain process, cool transportation offers greater flexibility in narrowing the spatial gaps in supply and demand, as well as ensuring products from major production areas arrive fresh and safe at high consumption hubs.

In order for cool transportation to improve efficiency in interregional food markets, the information asymmetry between sellers in one place and buyers in another must be addressed. Buyers often rely on observable characteristics to infer a product's unobservable characteristics, such as taste and nutritional content. In most value chains, buyers cannot directly know about a product's unobservable characteristics and information about the quality is not generally circulated (Fafchamps et al., 2008), though there are potentially large quality premiums (Vandeplass and Minten, 2015). Further, sellers may not have effective means of ascertaining quality that they can readily communicate with buyers. Distance between origin and destination areas exacerbates the asymmetry of product quality information as the transporter comes in as an intermediary. In a classic example from the labor market, educational attainment is taken as an observable signal of ability under some circumstances, which leads to an inefficient equilibrium (Spencer, 1973; Rothchild and Stiglitz, 1976). Here, workers (students) are encouraged to invest in education to signal their ability rather than increase labor productivity, in contrast to the standard human capital theory (Becker, 1962). A simple analogy applies in the case of tomato; the role of signals is important when supplying tomato to distant markets, where tomatoes from different origins—and thus of different quality—are aggregated.

Despite claims about the economic and nutritional benefits of cool transportation in sub-Saharan Africa, including Nigeria, empirical evidence gaps on the impacts of this post-harvest technology on outcomes such as income, food security, nutrition, and employment remain.<sup>5</sup> Using a randomized controlled trial (RCT), this study aims to measure the economic impacts of cool transportation among marketers and producers in three vegetable markets in the northeast region of Nigeria. For this study, fresh tomatoes

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<sup>5</sup> Recent works using RCTs include Chegere et al. (2022) and Shukla et al. (2023).

were transported in temperature-controlled trucks from high-production areas of three northeast states (Plateau, Bauchi, and Gombe) to two major southern cities, Lagos and Port Harcourt. Access to the cool transportation service was randomly assigned to marketers in the origin markets. The intervention also uses reusable plastic crates.<sup>6</sup> A supplementary experiment was also introduced to study the effect of labels that improve the product information. Further details of the experiment are described in Section 3.

Overall, the key findings of this paper are two-fold. First, the impact of cool transportation was large and statistically significant to the supply side in our partial equilibrium setting. Sales price, revenues, and profits significantly increased for marketers who received access to cool transportation. A significant portion of sales price increase is attributed to refrigeration, that is, quality preservation through cooling. About 66 percent of this increase comes from cooling. Transportation accounts for only 34 percent. Second, we also found that labeled crates were priced higher than unlabeled crates, though the average quality of labeled and unlabeled cases of tomatoes is the same.

The remaining sections of the paper are organized as follows. The next section describes study sites and population. The experimental design and estimation strategy are described in Sections 3 and 4, respectively. Section 5 shows empirical results. Concluding remarks are made in the final section.

## **2. STUDY SITES AND POPULATION**

### **Study sites**

With support from the Government of Japan, IFPRI partnered with the Nigerian Federal Ministry of Agriculture and Food Security, Darjhas Health and Agric Development, the University of Jos, and three local vegetable market unions (VMUs), namely, Farin Gada, Muda Lawal, and Yan Gwari operating in the northeast cities of Jos, Bauchi, and Gombe, respectively.

[Figure 1 to be inserted]

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<sup>6</sup> Yami et al. (2025) carefully examined the adoption behavior on plastic crates in Kano, Nigeria.

Figure 1 shows the geographic locations of the origin and destination markets: the yellow line is a common route from the origin location to the two market destinations, the red line shows the route to Lagos, and the blue part shows the route to Port Harcourt. Under this project, half of the fuel cost of transportation was subsidized, and the rest was covered by the users. The subsidy encouraged marketers to participate in the experiment.

### **Sample Properties**

From each of the three study areas (Jos, Bauchi, and Gombe states), 200 marketers were randomly selected from the population of tomato marketers. Thus, our total study population is 600 marketers. Baseline data were collected from October 17 to November 5, 2023 and identified (a) the marketers in the baseline sample who wished to participate in the cool transportation experiment (participants) and (b) those who did not (non-participants). As a result, 331 marketers indicated their willingness to participate; the remaining 269 marketers indicated otherwise. Out of the total 331 marketers, 120 marketers—that is, 40 from each of the three markets—were randomly assigned into the treatment group. The remaining 211 marketers became the control group.

### **Data and descriptive summary**

Table 1 presents descriptive statistics of baseline variables in the three markets that we can use to compare similarities and differences. Overall, the baseline samples of the three markets look quite similar. Interestingly, about 28 percent of the sample marketers have used cold storage, but the proportion of cold storage users is very small at the time of baseline survey. In Bauchi, more than 50 percent of the sample marketers reported using cold storage at the baseline, yet only 7 percent are currently using cold storage. In Jos and Gombe, only 3.5 percent of marketers are currently using cold storage. In all markets, the current utilization of cold storage is quite low. Similarly, only 2 percent of the sample marketers transport (store) products in cool transportation (4.5 percent in Bauchi, 1.5 percent in Gombe, and none in Jos). More strikingly, only 0.5 percent of the marketers store products in cold storage (1 percent in Jos, 1.5

percent in Gombe, and none in Bauchi). The observation is very clear: both cold storage and cool transportation are uncommon in the three markets.

[Table 1 to be inserted]

On the other hand, we see differences in the storage in non-cold containers, the ownership of storage space, and storage size across the three markets. Roughly 50 percent of the sample marketers use non-cool transportation, but there are clear differences across the three markets. In Jos and Gombe, nearly 70 percent and 64 percent of the markets use non-cool transportation, respectively. By contrast, only 15 percent of marketers from Bauchi use this method. In Bauchi, a large proportion of the marketers (80 percent) own storage space, and the space is relatively large, compared to just 14.5 percent and 27.5 percent from Jos and Gombe, respectively. The storage size is relatively large in Bauchi (35 tons), whereas storage size in Jos and Gombe hold around 5.7 and 1.6 tons, respectively.

The three markets also have different scales of tomato sales. Jos is much larger than Bauchi and Gombe. The Jos market sells more than 12 tons of tomatoes per week. This figure is about 5.2 tons and 4 tons in Bauchi and Gombe, respectively. By this metric, Jos is the more dominant wholesale market for tomatoes.

[Table 2 to be inserted]

Table 2 compares characteristics between participants and non-participants on the one hand, and between the treatment and control groups on the other hand. First, both the participants and non-participants are expected to have different characteristics due to the self-selection process. The table points to various variables, the means of which are found to be statistically different between the two groups. For example, the marketers who store products in cold storage are more likely to be willing to participate in cool transportation, but many of them do not own (non-cold) storage space. The participants were willing to pay less for cool transportation and estimated a lower current price for tomatoes per crate and a larger number of crates to transport in the intervention.

Second, the treatment and control groups are statistically comparable in Table 2. There are only a few variables that show significant differences: used cold storage, stored in cold storage, willingness to pay for cool transportation, and expected price per crate at the destination. In the sample, the treatment group

is more likely to have used cold storage and store products in cold storage. They are willing to pay less for cool transportation and expect a higher price per crate at the destination. All of these above are, however, at the 10-percent significance level.

## **Sales Prices**

Figure 2 displays a snapshot observation on price differences in the first round from Jos to Lagos: purchasing price for a plastic crate of tomatoes (approximately 20 kg) and sales prices at both the destination market (gross and net of transportation cost) and the origin market. The profit margin<sup>7</sup> at the origin market is 2,500 Naira, and the gross profit margin by cool transportation to the destination is 8,160. The net profit margin by cool transportation, however, is 6,360, indicating potentially large economic gains from cool transportation.

[Figure 2 to be inserted]

Figure 3 shows sales prices at four origin markets, and sales prices in Port Harcourt for tomatoes transported from those origin markets. There are two important observations. First, sales prices are higher in Port Harcourt than in the origin markets located in the northern or northeast regions. This reflects large supply–demand gaps between the origin markets and Port Harcourt in southern region. Second, tomatoes from different origins are priced differently in the destination market. This likely reflects (perceived) quality differences in tomatoes from different production areas. In this sense, tomatoes from Jos are considered to be the highest quality in the destination market. Adverse selection is possible in this setting; tomatoes not from Jos can be priced high if consumers cannot distinguish perfectly between tomatoes that

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<sup>7</sup> The profit margins per 20 kg of tomatoes are defined as follows: the profit margin at the origin market = sales price minus purchasing price at the origin market; the gross profit margin by cool transportation to the destination = sales price at the destination market minus purchasing price at the origin market; the net profit margin by cool transportation = sales price at the destination market minus transportation cost and purchasing price at the origin market.

are from Jos and those that are not. Table A1 shows price differentials observed on different days in a week.

[Figure 3 to be inserted]

### **3. EXPERIMENTAL DESIGNS**

#### **Cool Transportation Experiment**

The study comprises 40 marketers from each study market who have access to cool transportation in the manner described below and 16 marketers randomly selected from the pure control group. The 40 marketers in each market were further grouped into five sub-groups, that is, 8 marketers per sub-group. During each round, one sub-group serves as a treatment group, and the remaining 4 sub-groups serve as a round-specific control group. These sub-groups rotate each round.

Follow-up data collection was conducted in each round, approximately once every week. The data were collected from the market agents at the destination market on trading activities of perishable horticulture crops in the most recent transaction cycle, which covers (i) prices of the products delivered to the destination market, (ii) sales of the products delivered to the destination market, (iii) food loss/spoilage, and (iv) relationships.

The RCT was implemented through two phases that initially started in early 2024. Phase I was implemented in January and February 2024; Phase II was implemented between October 2024 and March 2025. Details of the operations are shown in Table A2. In Phase I, as a pilot stage, the destination market was Mile 12 market in Lagos only, but the scope was expanded to include Port Harcourt as a second destination market in Phase II. Thus, price comparisons between the two destinations are possible in Phase II.<sup>8</sup> In fact, the marketers preferred Port Harcourt because that location does not receive tomatoes

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<sup>8</sup> The RCT participants were the same in Phases I and II. In Phase II, market unions assessed the market conditions, especially sales prices, and decided the destination market.

from many northern states, such as Kano and Kaduna, and therefore generally enjoys a higher, stable price.

In Phase I, of the three origin markets, only Jos and Gombe participated, given the scarcity of tomatoes in Bauchi. Phase II was launched in October 2024 with a unique arrangement that all tomatoes be loaded in Jos even for the marketers in Bauchi and Gombe due to unequal supplies of tomatoes across the three markets in the beginning of the season. Moreover, though we have three new trucks for Phase II, the third truck became operational only after November 18 due to the required repairs to electronic connections of the cooling system and the cooling system compressor, which affected the operation for Bauchi.

We have 56 marketers in the sample. Note that the control group for the follow-up rounds is a random sample ( $n=16$ ) of the pure control group. In each round, a treatment group of 8 marketers can load tomatoes. In this setting, we have 2,520 observations in the case of 15 rounds (and 1,680 observations in the case of 10 rounds). There are five preassigned 5 treatment sub-groups,  $k = A, B, C, D, E$ . The rotation method is illustrated in Table 3.<sup>9</sup>

[Table 4 to be inserted]

## Labelling Experiment

A labeling experiment was attached to the first rounds in Jos and Gombe to Lagos and the fifth round in Jos to Port Harcourt. A truck carries 600 to 700 crates of tomatoes and about half of the crates were randomly selected to be labeled. Figures 4a and 4b show the labels for Jos and Gombe, respectively. As the destination agents were not informed of the experiment, it is an unannounced surprise to the destination market.

[Figures 4 to be inserted]

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<sup>9</sup> The rotation method implies that marketers in the preassigned 5 treatment groups can estimate approximately when they will gain access to cool transportation. Potentially, ex-ante behavioral adjustments are possible in this setting, but the analysis below abstracts from this issue.

In theory, we cannot predict the reaction of the destination market, that is, consumers and marketers, to the label. The labeled crates can be priced higher or lower than the unlabeled ones. However, it is important to note that all labeled crates will be priced uniquely in the market, and all unlabeled crates are also priced accordingly.

As shown in Figures 4a and 4b, the label contains the information on (a) the project (IFPRI), (b) the transportation method (cool transportation), and (c) the origin of tomatoes, Jos or Gombe in this case. Combined together, the label is considered a signal of relatively higher-quality tomatoes.

### 3. ESTIMATION STRATEGY

We estimate the impacts of cool transportation on sales price, revenue and profit. Let the indexes ( $i, t, m$ ) represent marketer  $i$ , time  $t$  (round), and market  $m$ , respectively. Let  $Y_{(i,t,m)}$ ,  $Tr_{(i,t,m)}$ ,  $m_i$ , and  $m_t$  represent the outcome variable, the treatment indicator, location fixed effects and market-round fixed effects, respectively. To estimate the treatment effect of participation in cool transportation, we use the following basic model:

$$Y_{(i,t,m)} = \varphi + \beta Tr_{(i,t,m)} + \gamma X_i + m_i + z_{it} + \varepsilon_i \quad \text{----- (1)}$$

Where  $Y_{(i,t,m)}$  is the outcome of interest for marketer  $i$  and  $Tr_{(i,t,m)}$  is a dummy variable taking a value of 1 if marketer  $i$  received a cool transport service and 0 otherwise.  $X_i$  is a vector of covariates to control for observable imbalances across groups and increase precision in our estimates, and  $\gamma$  is a vector of coefficients for the controls. We control individual-level and round-specific fixed factors using individual marketer fixed effects ( $m_i$ ), and market-round fixed effects using ( $z_{it}$ ).  $\varepsilon_i$  is a zero mean error term assumed to be homoscedastic, and  $\beta$  measures the average treatment effect on the treated.

Marketer  $i$  in market  $m$  is in the treatment group, in which  $i$  will use cool transportation in rotations (otherwise, serves as control until  $i$ 's turn comes) or will be in the pure control group. There are five

treatment sub-groups in each market, denoted by A, B, C, D, and E in Table 4. The outcome variable  $y(i, t, m)$  is sales price, revenue, and profit for  $i$  in round  $t$ . There are three origin markets,  $m = \text{Jos, Bauchi, and Gombe}$ . The total number of rounds ( $t$ ) is 15 for Jos and Gombe, and 10 for Bauchi (see Table A2). In the estimation of the sales price equation, we compare two modes: (a) cool transportation and non-cool transportation and (b) cool transportation and origin market sales. Marketers can choose modes in each round, but the round-specific treatment group is exclusively allowed to use cool transportation. We will know the impact of cooling in (a) and that of cooling and transportation combined in (b). Therefore, the two impact estimates from (a) and (b) enable us to decompose into the parts attributable to cooling and transportation. In the estimation of revenue and profit equations, we use the aggregate of different modes: cool transportation, non-cool transportation, and origin market sales.

The analysis of labeling effects is conducted at the crate level. As part of the cool transportation RCT, the experiment was conducted only in three rounds: the first and fifth rounds in Jos, and the first round in Gombe. Half of the plastic crates were labeled as described, and sales prices in the destination market were recorded.

$$Y_{(c,m,t)} = \varphi + \theta L_{(c,m,t)} + \gamma X_i + m_i + z_{it} + \varepsilon_i \quad \text{-----} \quad (2)$$

where  $Y_{(c,m,t)}$  is the sales price for plastic crate  $c$ ,  $L_{(c,m,t)}$  is the label indicator, and  $\theta$  measures the average effect of labeling. This experiment was nested in only three rounds, as described, so the impact estimate in (1) marginally reflects the effect of labeling.

## 4. RESULTS

### Impacts of Cool Transportation

Table 4 compares sales price, revenue, and profit per crate of 20 kg tomatoes for cool transportation, non-cool transportation, and origin market sales. Note that marketers can use cool transportation (only when

allowed), non-cool transportation, and must sell at the origin market. Cool transportation shows the largest values across all the outcome variables, followed by non-cool transportation and origin market sales in revenue. Origin market sales, however, show a higher profit than non-cool transportation.<sup>10</sup> This could be due to deteriorated quality during non-cool transportation,<sup>11</sup> but the profit depends on the sales price at the destination.

[Table 5 to be inserted]

Table 5 shows the impact estimates from Rounds 1–15 in Gombe, 1–15 in Jos, and 1–10 in Bauchi. The estimation includes market-agent fixed effects and market-round fixed effects. Columns 1 and 2 show the impact of cool transportation on sales price in two cases of alternative sales options: non-cool transportation (Column 1) and origin market sales (Column 2).<sup>12</sup> The estimated impacts are quantitatively larger as well as statistically significant (standard errors are in parentheses). As expected, the impact is larger when the alternative sales option is the origin market sales price. Strikingly, the percentage increases are about 55 (Column 1) and 123 (Column 2), respectively.

[Table 6 to be inserted]

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<sup>10</sup> Origin market sales show a higher profit than non-cool transportation, but this could be due to a significant loss rate in non-cool transportation and/or fuel costs. However, it is important to note that standard deviations are relatively large, so the comparison is not statistically conclusive.

<sup>11</sup> Table A3 shows preliminary findings on quality deterioration in non-cool transportation. The proportion of bad quality is ranged between 12.0 to 19.4 percent. Bad quality tomatoes were priced about half that of good quality tomatoes. Still, sales prices for cool transported tomatoes were higher than the above two cases. Revenues in cool transportation are therefore higher than that of non-cool transportation.

<sup>12</sup> When cool transportation mode is available via the RCT, marketers use this mode (they did not use non-cool transportation) and can sell tomatoes in the origin market. If the cool transportation mode is not available, they can use non-cool transportation and/or sell in the origin market. In this sense, the exogeneity of cool transportation mode is assured, while marketers resort to non-cool transportation and/or sales in the origin market when cool transportation is not available.

The impact can be decomposed into two parts: (i) those attributable to the transportation of tomatoes from the origin to the destination market (transportation only) and (ii) those attributable to quality preservation through refrigeration (cooling and transportation). By using the estimates in Columns 1 and 2, we can conclude that 33.76 percent of the sales price impact comes from market access, that is, from origin to destination markets (with loss due to non-cool transportation); and 66.24 percent comes from quality preservation, that is, refrigeration to keep tomatoes fresh (no loss). A large portion of the sale price increase is attributed to cooling.

Next, we look at impacts on revenue and profit.<sup>13</sup> The estimation pools revenues (profits) from cool transportation, non-cool transportation, and origin markets sales. The impacts are large and statistically significant for revenue and profit, respectively, in Columns 3 and 4.

### **Impacts of Improved Information (product labeling)**

In three rounds, we attached labels to a random sample of crates. This experiment aims to identify whether premiums can be attributed to better information on the quality inferred from the origin, cool transport, and IFPRI. The destination agent was not informed of this experiment.

[Figure 5 to be inserted]

Figure 5 compares the sale prices for the labeled and unlabeled crates. The experiments were conducted in the first rounds from Jos and Gombe to Lagos and in the fifth round from Jos to Port Harcourt. Labeled crates are priced higher than the unlabeled crates. Note that the quality of tomatoes is orthogonal to labels as crates were randomly labeled. About 10–20 percent of the sale prices are attributed to improved information—in other words, a price premium. The sales price data are shown in Table A4.

[Table 6 to be inserted]

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<sup>13</sup> Revenue and profit are defined as (a) revenue = sales price \* volumes sold and (b) profit = revenue – total purchasing cost – total transportation cost.

Table 6 shows the estimation results using the crate-level data. In Round 1, the number of crates was 614 (307 labeled) in Jos and 694 (347 labeled) in Gombe; in Jos Round 5, the number of crates was 600 (300 labeled). The results are clear: the label significantly increased sales prices.

## 5. CONCLUSIONS

A randomized controlled trial was introduced to examine economic returns to cool transportation connecting three vegetable producing states (Jos, Gombe, and Bauchi states) in northeast Nigeria to two large demand centers (Lagos and Port Harcourt) in the southern regions of Nigeria. The impact of cool transportation was large and statistically significant to the supply side in our partial equilibrium setting. Sales price at the destination market, revenues, and profits significantly increased for marketers who had access to cool transportation. A larger portion of sales price increase is attributed to refrigeration, that is, quality preservation through cooling. About 66 percent of the increase comes from cooling, and only 34 percent from transportation, that is, better access to consumption hubs of southern Nigerian markets.

A label was attached to a random sample of crates to signal product quality in such a way that the quality of tomatoes is orthogonal to the labels. The destination market agents were also not informed of the experiment. The label contains information about (a) the project (IFPRI), (b) the transportation method (cool transportation), and (c) the origin of tomatoes (Jos or Gombe). The study showed that labeled crates were priced higher than unlabeled crates, though the average quality of tomatoes in both the labeled and unlabeled crates is the same.

The results indicate significant economic gains can be generated not only by narrowing the supply–demand gaps through market linkages between the highly productive northern Nigerian states and consumption hubs in the southern region but also by potentially mitigating asymmetric information through product labeling. Note that our study is a partial equilibrium setting, in which impacts only go to the origin state actors. If cool transportation is scaled up to cover a large portion of interregional trades between the northern and southern regions of Nigeria, we can expect general equilibrium effects. That is,

fresh and nutritious high-quality tomatoes from Nigeria's northern states will be widely available in southern states, and they will be much more affordable.

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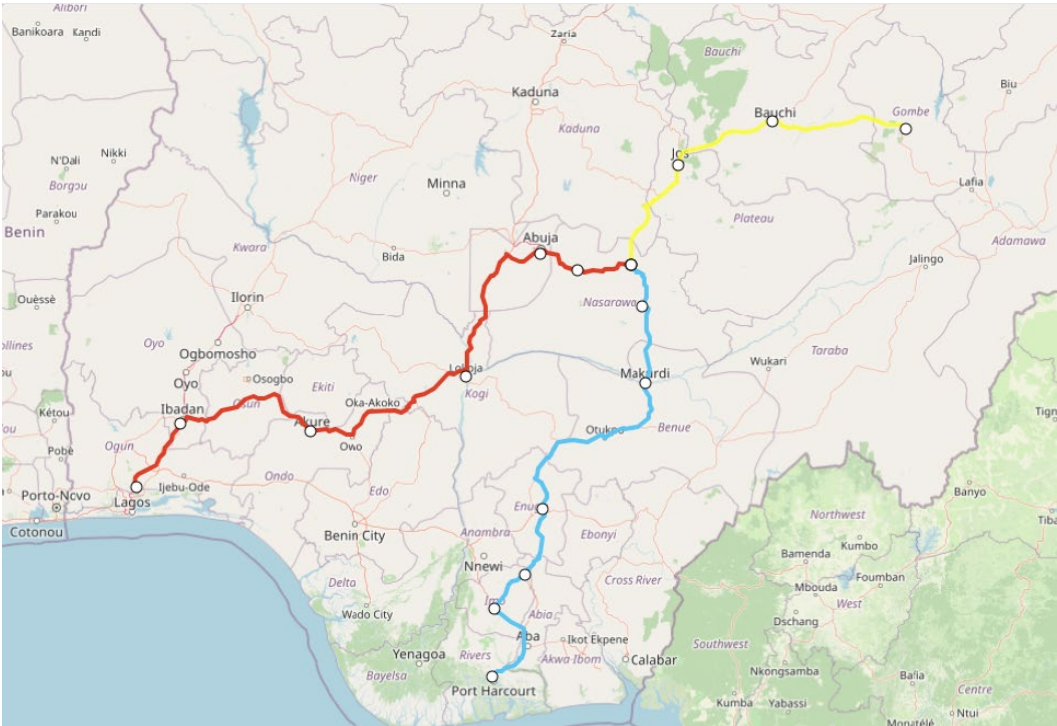
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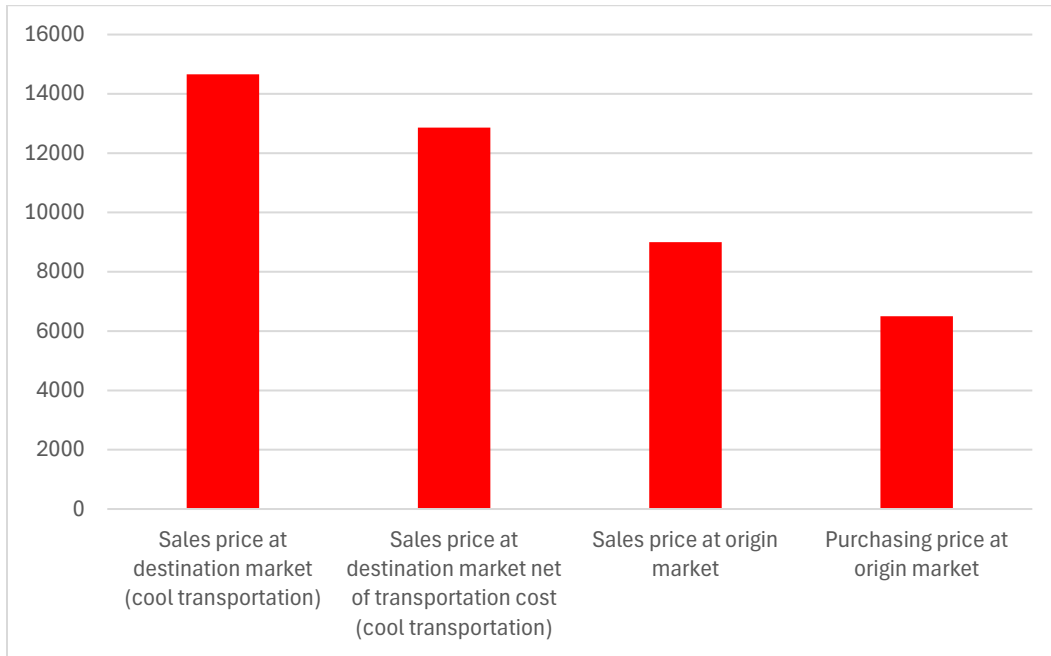
Figure 1. Jos/Bauchi/Gombe to Lagos/Port Harcourt



Source: Author’s calculations.

Note: Red and blue routes lead to Legos and Port Harcourt, respectively.

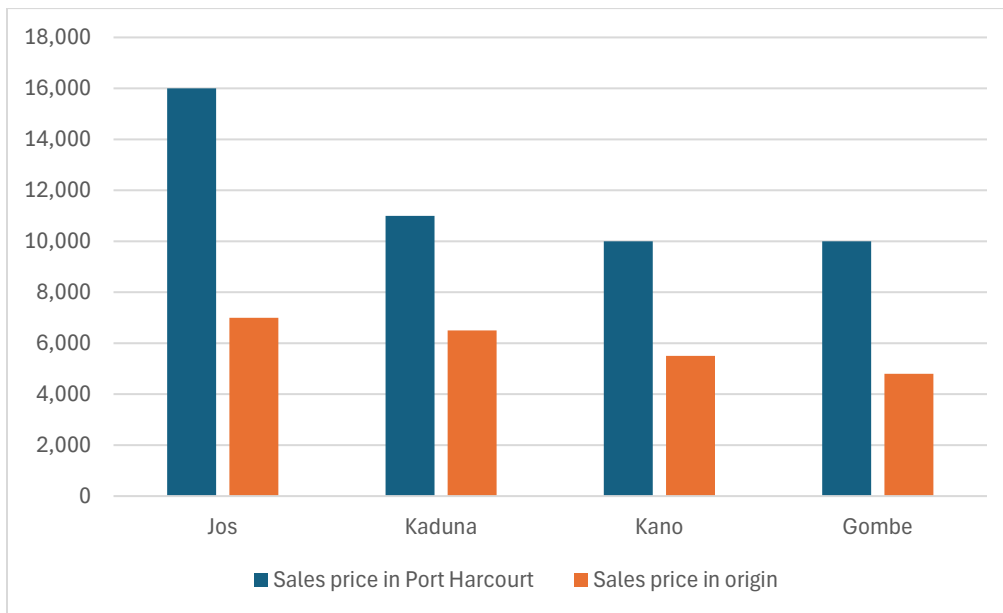
**Figure 2. Returns to Cool Transportation**



Source: RCT round surveys.

Note: Sales price and purchasing price are per crate (approximately 20 kg of tomatoes). Transportation cost is also calculated per crate.

**Figure 3. Sales Prices in Origin and Port Harcourt**



Source: Destination market survey.

Note: Mode of transportation is non-refrigerating trucks (non-cool transportation).

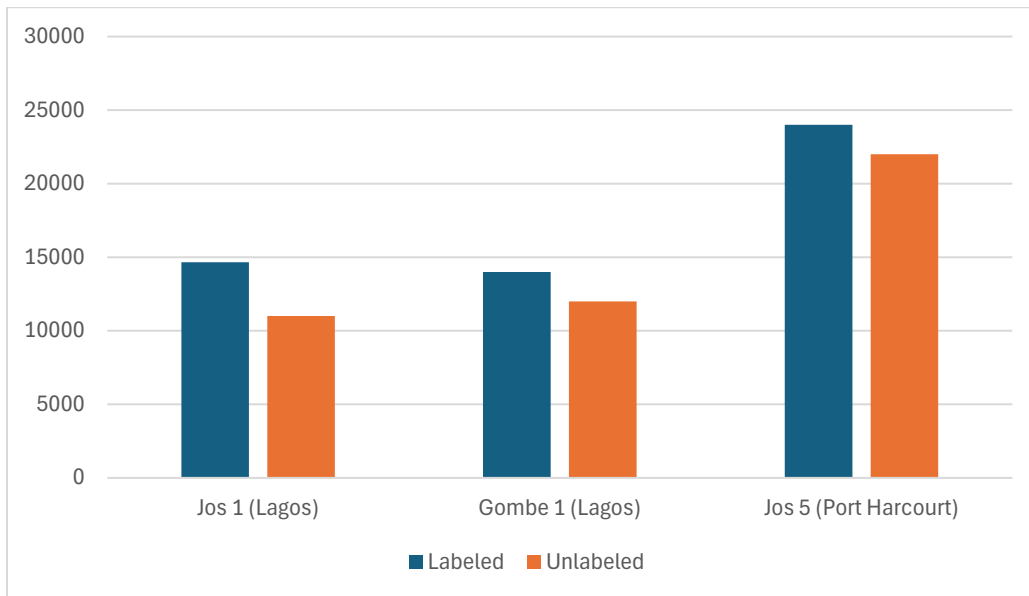
Figure 4. (a) Label for Jos and (b) Label for Gombe



(c) Photo



**Figure 5 Prices for Labeled Crates and Unlabeled Crates**



Source: RCT round surveys.

Note: Sales prices in Lagos for Jos Round 1, Gombe Round 1, and in Port Harcourt for Jos Round 5.

**Table 1. Summary Statistics in Three Markets**

<b>Variable</b>	<b>All markets</b>	<b>Jos</b>	<b>Bauchi</b>	<b>Gombe</b>
<b>Position (Owner)</b>	99.17	97.5	100	100
<b>Used cold storage in the past</b>	27.67	11.5	51.5	20
<b>Using cold storage now</b>	4.67	3.5	7	3.5
<b>Is commission agent</b>	67.83	93.5	50	60
<b>Is Wholesaler</b>	91.33	82	93	99
<b>Grow crops by self</b>	32.83	45.5	23.5	29.5
<b>Sells in other markets</b>	62.17	58	78	50.5
<b>Crop sole ownership (%)</b>	93.67	96.5	85.5	99
<b>Selling experience (years)</b>	16.79	16.44	15.99	17.94
<b>Producing experience (years)</b>	3.24	4.68	1.76	3.29
<b>Age</b>	40.72	40	44.16	38.02
<b>Household Size</b>	9.19	8.56	9.72	9.28
<b>State Native</b>	86.33	71	97.5	90.5
<b>Education (years)</b>	9.08	9.63	8.23	9.26
<b>Is member of trade association</b>	91.5	79.5	99	96
<b>Sells tomatoes</b>	60.33	86	19.5	75.5
<b>Quantity of tomatoes sold (kg)</b>	7910.58	12215.01	3647.69	4108.52
<b>Purchase from someone</b>	53.5	67	19.5	74
<b>Stores in cool transport</b>	2	0	4.5	1.5
<b>Stores in cold storage</b>	0.5	1	0	0.5
<b>Stores in non-cool transport</b>	49.5	70	15	63.5
<b>Owns a storage space</b>	41.17	14.5	81.5	27.5
<b>Storage space (tons)</b>	24.09	5.66	34.96	1.56
<b>Willingness to pay for cool transport</b>	1592.14	1884.64	1341.9	1549.9
<b>Estimated current price (per crate)</b>	9025.5	7824	10767.5	8485
<b>Estimated transportation capacity (crates)</b>	129.32	146.32	91.42	150.22
<b>Expected price (per crate)</b>	26206.67	26030	28410	24180
<b>Concerned about transportation loss</b>	99.83	100	99.5	100
<b>Willingness to participate</b>	55.17	64	46.5	55
<b>Number of observations</b>	600	200	200	200

Source: Baseline survey.

Note: Table shows variable means.

Table 2. Balance

Variable	Mean	Participants	Non-participants	Treatment	Control
Position (Owner)	99.17	98.49	100**	97.5	99.05
Used cold storage in the past	27.67	30.82	23.79*	36.67	27.49*
Using cold storage now	4.67	5.74	3.35	5.83	5.69
Is commission agent	67.83	70.39	64.68	69.17	71.09
Is Wholesaler	91.33	85.8	98.14***	85	86.26
Grow crops by self	32.83	28.1	38.66***	26.67	28.91
Sells in other markets	62.17	56.5	69.14***	57.5	55.92
Crop sole ownership (%)	93.67	98.19	88.1***	99.17	97.63
Selling experience (years)	16.79	17.95	15.36***	17.48	18.22
Producing experience (years)	3.24	2.8	3.8**	2.55	2.94
Age	40.72	40.65	40.81	40.12	40.96
Household Size	9.19	9.84	8.39***	9.92	9.79
State Native	86.33	85.5	87.36	81.67	87.68
Education (years)	9.08	8.94	9.27	8.99	8.91
Is member of trade association	91.5	87.92	95.91***	86.67	88.63
Sells tomatoes	60.33	61.03	59.48	55.83	63.98
Quantity of tomatoes sold (kg)	7910.58	8402.02	7290.12	7701.19	8749.84
Purchase from someone	53.5	53.78	53.16	49.17	56.4
Stores in cool transport	2	1.51	2.6	0.83	1.9
Stores in cold storage	0.5	0.91	0*	2.5	0*
Stores in non-cool transport	49.5	48.34	50.93	42.5	51.66
Owens a storage space	41.17	32.63	51.67***	34.17	31.75
Storage space (tons)	24.09	23.57	24.48	20.55	25.43
Willingness to pay for cool transport	1592.14	1537.24	1659.7**	1454.17	1584.49*
Estimated current price (per crate)	9025.5	8490.94	9683.27***	8795.83	8317.54
Estimated transportation capacity (crates)	129.32	165.45	84.86***	161.17	167.89
Expected price (per crate)	26206.67	24404.83	28423.79***	25570.83	23741.71*
Concerned about transportation loss	99.83	99.7	100	99.17	100
Willingness to participate	55.17	100	0	100	100
Number of observations	600	331	269	120	211

Source: Baseline survey.

Note: \*\*\*1%, \*\*5%, and \*10% significance level. Standard errors were computed without clustering.

**Table 3. Illustration on Rotations**

Round	Destination	Treatment (n = 8)		Control (n = 32)			Pure Control (n = 16)
1st	Lagos	D	A	B	C	E	X
2nd	Lagos	A	D	B	C	E	X
3rd	Lagos	C	A	B	D	E	X
4th	Lagos	E	A	B	D	C	X
5th	Lagos	B	A	C	D	E	X
6th	Port Harcourt	C	A	B	D	E	X
7th	Port Harcourt	D	A	B	C	E	X
8th	Port Harcourt	A	D	B	C	E	X
9th	Port Harcourt	B	A	C	D	E	X
10th	Port Harcourt	E	A	B	D	C	X

Note: Rounds include only up to the 10<sup>th</sup> round for illustration. Treatment is randomly ordered among sub-groups.

**Table 4. Descriptives**

		N obs	Mean	Std
Sales price	Cool transportation	320	23020.9	8849.6
	Non-cool transportation	1,575	15198.2	7632.7
	Origin market	629	10239.9	4272.2
Revenue	Cool transportation	320	1736357.0	942274.6
	Non-cool transportation	1,611	860110.3	692843.7
	Origin market	1,116	438927.3	866047.2
Profit	Cool transportation	320	755999.3	550968.3
	Non-cool transportation	1,612	74077.4	309024.1
	Origin market	1,116	102660.7	775825.1

Source: RCT round surveys.

**Table 5 Impacts of Cool Transportation on Sales Price, Revenue and Profit**

	<b>Sales price</b>	<b>Sales price</b>	<b>Revenue</b>	<b>Profit</b>
	<b>Cool vs. non-cool</b>	<b>Cool vs. origin</b>	<b>Pooled</b>	<b>Pooled</b>
<b>Cool transportation</b>	8340.22*** (279.39)	12590.67*** (369.18)	840361.3*** (57335.3)	649284.7*** (40145.7)
<b>Marketer Fixed Effects</b>	Yes	Yes	Yes	Yes
<b>Market-Round Fixed Effects</b>	Yes	Yes	Yes	Yes
<b>Constant</b>	Yes	Yes	Yes	Yes
<b>Sample-size</b>	1,893	947	2,180	2,181
<b>% Increase</b>	54.88	122.96		
<b>Difference in sales price 33.76% - Reallocation, i.e., origin to destination markets</b>				
<b>66.24% - Quality preservation, i.e., cooling to keep fresh (no loss)</b>				

Source: RCT round surveys.

Note: \*\*\*1%, \*\*5%, and \*10% significance level. Robust standard errors were used with origin-round clusters.

**Table 6 Labelling effects**

	<b>Sales price</b>	<b>Ln sales price</b>
<b>Labelled</b>	2534.19**	0.1759*
	(544.34)	(0.0565)
Origin market-round fixed effects	Yes	Yes
R squared	0.9936	0.9799
# obs	1908	1908

Source: RCT round surveys.

Note: \*\*\*1%, \*\*5%, and \*10% significance level. The above estimation uses crate-level data. The number of observations (crates) are 614, 694, and 600 in Jos Round 1, Gombe Round 1, and Jos Round 5, respectively. Robust standard errors were used with origin-round clusters.

**Table A1. Tomato Prices per 20 kg**

<b>North/Northeast</b>		<b>Feb 17</b>	<b>Feb 18</b>	<b>Feb 19</b>	<b>Feb 20</b>	<b>Feb 21</b>
Tomato in:	Jos	7,500	7,500	7,000	7,000	7,000
	Kaduna	5,500	6,000	6,000	6,500	6,500
	Kano	5,000	5,200	5,000	5,500	5,500
	Gombe	4,800	4,500	4,300	4,800	4,800
<b>Port Harcourt</b>						
Tomato from:	Jos	15,000	15,000	16,000	16,500	16,000
	Kaduna	11,000	11,000	10,000	10,000	11,000
	Kano	10,000	10,000	10,000	10,000	10,000
	Gombe	10,000	10,000	9,500	10,000	10,000

Source: Destination market survey.

Note: Sales prices at four origin markets and in Port Harcourt as destination market in the case of non-cool transportation.

**Table A2. RCT Rounds: Date/Time of Departure in Origin Markets and Arrival in Destination Markets**

Round	Date of Departure	Time of departure	Date of Arrival	Time of Arrival
<b>Jos</b>				
1 <sup>st</sup>	13.03.2024	08:30 pm	15.03.2024	01:37 am
2 <sup>nd</sup>	21.10.2024	10:00 pm	23.10.2024	04:36 am
3 <sup>rd</sup>	31.10.2024	09:59 pm	02.11.2024	05:06 am
4 <sup>th</sup>	05.11.2024	04:03 pm	08.11.2024	02:20 am
5 <sup>th</sup>	11.11.2024	05:14 pm	13.11.2024	03:47 am
6 <sup>th</sup>	20.11.2024	09:10 pm	22.11.2024	04:26 am
7 <sup>th</sup>	27.11.2024	07:25 pm	29.11.2024	04:15 am
8 <sup>th</sup>	02.12.2024	06:30 pm	04.12.2024	01:40 am
9 <sup>th</sup>	07.12.2024	08:20 pm	09.12.2024	02:15 am
10 <sup>th</sup>	14.12.2024	11:30 pm	16.12.2024	11:15 am
11 <sup>th</sup>	01.02.2025	11:00 pm	03.02.2025	02:41 am
12 <sup>th</sup>	08.02.2025	10:54 pm	10.02.2025	02:48 am
13 <sup>th</sup>	15.02.2025	10:30 pm	17.02.2025	02:56 am
14 <sup>th</sup>	22.02.2025	10:45 pm	24.02.2025	03:42 am
15 <sup>th</sup>	01.03.2025	10:56 pm	03.03.2025	03:42 am
<b>Bauchi</b>				
1 <sup>st</sup>	18.11.2024	01:15 pm	20.11.2024	12:48 am
2 <sup>nd</sup>	22.11.2024	07:30 pm	25.11.2024	03:58 am
3 <sup>rd</sup>	29.11.2024	02:23 pm	01.12.2024	10:21 am
4 <sup>th</sup>	06.12.2024	11:45 pm	08.12.2024	07:30 pm
5 <sup>th</sup>	13.12.2024	07:12 pm	15.12.2024	12:30 pm
6 <sup>th</sup>	03.02.2025	11:11 pm	05.02.2025	03:24 am
7 <sup>th</sup>	10.02.2025	10:20 pm	12.02.2025	04:15 am
8 <sup>th</sup>	17.02.2025	09:58 pm	19.02.2025	03:01 am
9 <sup>th</sup>	24.02.2025	10:26 pm	26.02.2025	03:20 am
10 <sup>th</sup>	03.03.2025	10:59 pm	05.03.2025	06:23 am
<b>Gombe</b>				
1 <sup>st</sup>	21.02.2024	05:14 pm	24.02.2024	02:15 am
2 <sup>nd</sup>	03.03.2024	08:57 pm	05.03.2024	04:15 am
3 <sup>rd</sup>	10.03.2024	09:11 pm	12.03.2024	12:32 am
4 <sup>th</sup>	21.03.2024	09:08 pm	23.03.2024	03:50 am
5 <sup>th</sup>	22.10.2024	09:46 pm	24.10.2024	04:08 am
6 <sup>th</sup>	01.11.2024	10:30 pm	03.11.2024	05:02 am
7 <sup>th</sup>	06.11.2024	10:58 pm	08.11.2024	06:21 am
8 <sup>th</sup>	12.11.2024	11:00 pm	15.11.2024	06:39 am
9 <sup>th</sup>	18.11.2024	11:03 pm	22.11.2024	05:47 am
10 <sup>th</sup>	24.11.2024	09:10 pm	26.11.2024	03:48 am
11 <sup>th</sup>	01.12.2024	12:00 Noon	03.12.2025	09:14 pm
12 <sup>th</sup>	07.12.2024	07:25 pm	09.12.2024	02:15 pm
13 <sup>th</sup>	15.12.2024	10:16 pm	17.12.2024	04:12 am
14 <sup>th</sup>	05.02.2025	11:00 pm	07.02.2025	03:40 am
15 <sup>th</sup>	12.02.2025	11:19 pm	14.02.2025	05:21 am

Source: RCT round surveys.

**Table A3. Sales Prices and Volumes of Good and Bad Quality Tomatoes after Non-cool Transportation**

Departure date	Travel hours	Bad quality			Good quality		
		Crates	kg	Price	Crates	kg	Price
March 1	38	165	3300	7500	835	16700	13500
March 2	40	176	3520	6000	824	16480	13500
March 3	40	152	3040	6500	848	16960	13000
March 4	41	120	2400	6000	880	17600	13500
March 6	41	189	3100	6500	911	18220	14000
March 8	40	141	2820	6000	859	17180	13500
March 10	40	138	2760	7000	862	17240	13500
March 11	38	167	3340	6500	833	16660	13500
March 13	39	194	2660	7000	806	16120	13500
March 15	39	153	3060	6500	847	16940	14500

Source: Destination market survey.

Note: Travel hours, sales prices, and volumes (the number of crates) are shown for spoiled tomatoes (bad quality) and fresh tomatoes (good quality)

**Table A4. Sales Prices of Labeled and Unlabeled Crates**

<b>Origin</b>	<b>Round</b>	<b>Destination</b>	<b>Date</b>	<b>Labelled</b>	<b>Unlabelled</b>	<b>Diff</b>
<b>Jos</b>	1	Lagos	03/15/2024	14,660	11,000	3,660
<b>Gombe</b>	1	Lagos	02/24/2024	14,000	12,000	2,000
<b>Jos</b>	5	Port Harcourt	11/13/2025	24,000	22,000	2,000

Note: The number of observations (crates) are 614, 694, and 600 in Jos Round 1, Gombe Round 1, and Jos Round 5, respectively. Half of the crates from each trip were labeled, that is, 307, 347, and 300, respectively.

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