Development Engineering 1 (2016) 4–11

Contents lists available at ScienceDirect

Development Engineering

journal homepage: www.elsevier.com/locate/deveng

Radio frequency (un)identification: Results from a proof-of-concept trial of the use of RFID technology to measure microenterprise turnover in Sri Lanka ☆

Suresh de Mel [a], Dammika Herath [b], David McKenzie [c,*], Yuvraj Pathak [c]

[a] University of Peradeniya, Sri Lanka
[b] Kandy Consulting Group, Sri Lanka
[c] World Bank, United States

ARTICLE INFO

Article history:
Received 20 April 2015
Accepted 30 June 2015
Available online 10 November 2015

JEL Codes:
O12
O16
C81
C93
M41

Keywords:
Microenterprises
Survey methods
Profit and sales measurement
RFID

ABSTRACT

Accurate measurement of stock levels, turnover, and profitability in microenterprises in developing countries is difficult due to the fact that the majority of these firms do not keep detailed records. We test the use of radio frequency identification (RFID) tags as a means of objectively measuring stock levels and stock flow in small retail firms in Sri Lanka. In principle this offers the potential to track stock movements accurately. We compare the stock counts obtained from RFID reads to physical stock counts and to survey responses. We have three main findings. First, current RFID-technology is more difficult to use, and more time-consuming to employ, than we envisaged. Second, the technology works reasonably well for paper products, but very poorly for most products sold by microenterprises: on average we were able to read only about one-quarter of the products tagged, and there was considerable day-to-day variation in read-efficiency. This results from technical issues arising from read efficiency being comprised by liquids, metal, and product stacking. Third, a comparison of survey responses and physical stock-takes shows much higher accuracy for survey measures than RFID. As a result, we conclude that this technology is currently unsuitable for improving stock measurement in microenterprises, except perhaps for a few products.

1. Introduction

In a 2008 nationally representative survey of urban micro-enterprises in Sri Lanka, 81.3 percent of firms with no employees say they do not keep any accounts for their business.[1] This lack of formal recordkeeping is true of many microenterprises around the developing world, and makes it challenging for researchers to collect accurate data on inventory levels, sales, and profits in such firms (Vijverberg, 1991; Daniels, 2001; De Mel et al., 2009). The large genuine volatility of incomes in such businesses (Collins et al., 2009; Fafchamps et al., 2012) can make recall more difficult, and make it harder to distinguish measurement error from actual fluctuations. A further complication arises in evaluations of interventions, where the receipt of a program (such as access to credit) may affect individual's incentives to report accurately, or, in the case of business training, may even change the accuracy with which respondents can report on their business. As a result many studies of microenterprises suffer from high levels of imprecision and of item-response on profits and sales, or otherwise struggle to measure these concepts at all (see McKenzie and Woodruff (2014) for a review).

Yet accurate measurement of inventory levels, turnover, and profits is crucial for answering many questions of economic interest, such as determining the returns to credit or training, to understanding choices between wage work and self-employment, and measuring levels of poverty and inequality. New technologies have begun to offer the potential to improve measurement in a number of domains (McKenzie and Rosenzweig, 2012), raising the question of whether technology can also provide an objective (not self-reported), accurate, and time- and cost-effective measure of business activity in microenterprises?

This paper reports on a trial of the use of radio frequency identification (RFID) tags to measure inventory levels and turnover

☆We gratefully acknowledge funding for this project from the Knowledge for Change (KCP) trust fund, and the assistance of Kandy Consulting Group and Innovations for Poverty Action in project implementation. Institutional Review Board (IRB) approval for this study was obtained from the IPA IRB (#:13 November-003).

* Corresponding author.
E-mail address: dmckenzie@worldbank.org (D. McKenzie).

[1] Data from the baseline of the Sri Lanka Longitudinal Survey of Enterprises (SLLSE). See De Mel et al. (2010) for survey details.

http://dx.doi.org/10.1016/j.deveng.2015.06.001

in Sri Lankan microenterprises. RFID tags are increasingly being used in large U.S. retailers like Kohls, Walmart, LLBean, and Best Buy[2] for inventory management. In principle one can apply the tags to new stock as it comes in, and then use a reader to measure stock levels at any point in time without having to physically scan items one by one as would be the case with bar codes. Measuring the flow of stock coupled with price data then can provide data on sales, which could then in turn be coupled with unit cost or mark-up data to provide a measure of profits.

We implement this process in 22 microenterprises in Kandy, Sri Lanka. We accompany the tagging of inventories with physical stock-takes, and with survey elicitation of inventory levels from the firm owners. This enables comparison of the accuracy of RFID reads compared to survey responses. In addition, we tested the accuracy of RFID tagging on a larger range of products in our field office in order to provide evidence on which types of products this technology works for best.

There are three main findings of this proof of concept trial. First, available off-the-shelf technology is more difficult to use and more cumbersome than we had envisaged, and than is suggested by media accounts of the spreading use of this technology. Setting up the system required a period of fine-tuning and overcoming technical obstacles, and then the time taken to scan inventory levels at a firm was approximately 30 min. per firm. Second, in terms of proof of concept, our results show that (i) it is possible to get firms to agree to use this technology; (ii) the technology is able to work reasonably well for paper products and some clothing items; but (iii) the read-efficiency of the technology is very poor for many products offered by microenterprises, and varies from day to day. This poor read efficiency results from technological constraints with reading the tags in the presence of interference from liquids, metals, and stacked products. As a result, RFID technology does not enable accurate measurement of stock levels or turnover in most microenterprises. Third, survey questions on stock levels are much more accurate in terms of matching the results of our physical stock counts, providing some reassurance that relying on survey self-reports can yield reasonably accurate measurement (although this should be caveated by noting that owners may have paid extra attention to these items because of the study and so our surveys may be unusually reliable).

The remainder of the paper is as follows. Section 2 provides an introduction to RFID technology, and discusses how it is currently used by large firms, and how it could be used in principle to provide measurement of turnover and profits in microenterprises. Section 3 provides details of our trial, including the technology used, how we selected firms, how the tagging process worked in practice, and our office trial. Section 4 provides the results, and Section 5 concludes. An online appendix provides photograph and video illustrations of the products used and the tagging process.

2. RFID technology and its use to measure inventory levels, turnover, and profits

2.1. RFID technology

Radio-frequency identification (RFID) technology uses radio frequency waves to transmit information.[3] The basic technology consists of an RFID tag and a reader. The RFID tag has an embedded microchip which allows it to store data, and an embedded antenna to transmit this information. Each chip contains an electronic product code (EPC) which allows for unique identification of the tags, along with customized information chosen by the user. The reader is a device that has one or more antennas that emit radio waves and receive signals back from the tag. This information can then be linked to a database on a computer.

There are two types of RFID tags: active and passive. Active tags have their own battery attached to them, and use this power to constantly emit their own signals. As a result they can communicate over ranges of 100 meters or more. An example is the E–Z Pass used to automatically pay tolls on some roads in the U.S. Active tags can be relatively large in size and can cost $15 to $50 per tag, so are typically not used to track inventories apart from a few large, high-value, items. In contrast, passive tags do not have their own power supply, and instead rely on the radio-frequency energy transmitted by the reader to run the circuitry on its chip and reflect a signal back to the reader. This reflection is a weaker signal, and so the reader has to be much closer to the tag in order to be able to read – typically distances of between 5 cm and 3 m depending on the strength of the antenna (Lee, 2003; Holloway, 2006). The range is larger the larger the antenna, which results in a larger tag. The passive tag is much smaller in size than the active tag (typically the size of a sticker or credit card), and considerably cheaper, averaging 20–30 cents per tag. As a result of its size and cost, it is the main type of tag used in inventory and supply chain management.

Passive RFID tags have been trialed for inventory-management in several large retailers in the U.S. and U.K., including Walmart, Marks and Spencer, Sainsburys, Dillards, and Bloomingdales.[4] The main use appears to have been in stockrooms, with these organizations using passive RFID tags to track and inventory large boxes or pallets of inventory. Williams (2008) notes that despite much hype about how RFID would take over retailing, it has been slow to get embraced on the sales floor. However, there have also been several trials of their usage for tracking individual products, with a recent example being fashion store Zara implementing the use of RFID tags in 2014 to track items from factory to point of sale.[5] One of the main barriers to more widespread usage at the individual product level has been cost, with the cost of a tag too high to justify use on high volume, low margin goods (Gillmore, 2011).

RFID technology in principle offers several advantages over barcodes. In particular, they can be programmed to store more information, which can be unique for each item. Common examples given are the possibility of adding expiration dates to perishable products, and manufacturing batch numbers to pharmaceutical products (allowing easy identification of which items to remove from shelves in case of a recall). Moreover, they do not require line of sight reading, and can enable inventory counts without the need to physically scan each item's barcode.

However, since passive tags rely on transmission of radio waves between the reader and tag and back, there are several factors that can prevent accurate reads (Roberti, 2013).[6] The three main issues are liquids, metals, and tag shadowing. Materials containing a large amount of water absorb radio-frequency energy, so that the tag fails to receive enough energy to reflect back a strong signal. Metal can reflect energy away from a tag, or reflect the tag's signal away from the reader. Finally, if items are stacked so that tags are lined up behind one another, the first tag can capture the reader's energy, shadowing the tags on items behind it. The result can be that the first item is read but those behind it are not. Typical

[2] E.g. http://www.rfid24-7.com/article/kohl%e2%80%99s-deploys-rfid-chain-wide-launches-consumer-engagement-apps/ (accessed 28 July, 2012).

[3] The description of RFID technology which follows is drawn from Violino (2005), Gaukler and Seifert (2007), and Holloway (2006).

[4] See for example the set of case studies at http://rfid.auburn.edu/research-papers.cfm.

[5] http://www.reuters.com/article/2014/07/15/inditex-zara-idUSL6N0PQ3MY20140715 (accessed August 1, 2014).

[6] These are typically not issues with active tags, which produce their own signals.