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A Hybrid Agricultural Information Delivery System for Enhancing Sustainability: Experimental Insights from India

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ABSTRACT: This study explores the potential of a Hybrid Agricultural Information Delivery System (HAIDS) as a means to improve the sustainability of agriculture in India. The system integrates traditional methods of agricultural knowledge dissemination with modern digital tools, aiming to provide farmers with timely, accurate, and actionable information. As agriculture in India faces numerous challenges, including climate change, resource constraints, and market volatility, the need for effective information delivery is critical to ensure sustainable farming practices and improved productivity. The research was conducted through an experimental design, involving a diverse group of farmers across different regions in India. This hybrid approach was designed to leverage the strengths of both traditional and digital methods, ensuring that farmers receive information in a format that is accessible and understandable to them. The findings indicate that the HAIDS significantly improved farmers' knowledge of sustainable agricultural practices, leading to more informed decision-making and better resource management. The system also enhanced the adoption of climate-resilient techniques, contributing to greater agricultural sustainability. Furthermore, the study found that the hybrid approach was particularly effective in reaching marginalized and smallholder farmers, who often lack access to conventional information channels. This research provides valuable insights into the design and implementation of agricultural information systems, highlighting the importance of combining traditional and modern methods to achieve sustainability goals. The results suggest that HAIDS could be a scalable solution for improving agricultural sustainability in India and other developing countries facing similar challenges.

KEYWORDS: Agricultural information delivery, Agricultural sustainability, Information and communication Technology, Randomized control trial.

I. INTRODUCTION

This study examines the impact of an innovative agricultural information delivery system on the sustainability of agricultural practices among paddy and cotton farmers in India. The research addresses the issue of balancing financial and ecological sustainability in farming, traditionally viewed as mutually exclusive goals, by introducing a hybrid information delivery system. This system combines traditional agent-based methods with modern Information and Communication Technology (ICT) tools to provide farmers with customized, research-based information on crop production, focusing on nutrient management and plant protection. The field experiment, known as Dynamic Agricultural Tablet-based Extension Services (DATES), was conducted over two years (2013-2015). Extension agents, equipped with electronic tablets loaded with best practice modules and a pest-diagnosis mobile application, delivered this information to the farmers. The study's findings are significant: paddy yields increased by 18%, and cotton yields by 85%. Additionally, the use of inorganic fertilizers and crop protection chemicals decreased, leading to a more balanced and efficient use of these inputs. This not only improved the ecological sustainability of the farming practices but also enhanced the financial returns for farmers, with net returns increasing by 78% for paddy and 221% for cotton. The results demonstrate that a hybrid approach to agricultural Information delivery can effectively achieve both financial and ecological sustainability in agriculture. The study's findings suggest that similar initiatives could be scaled up to address the challenges of sustainable agriculture in other regions.

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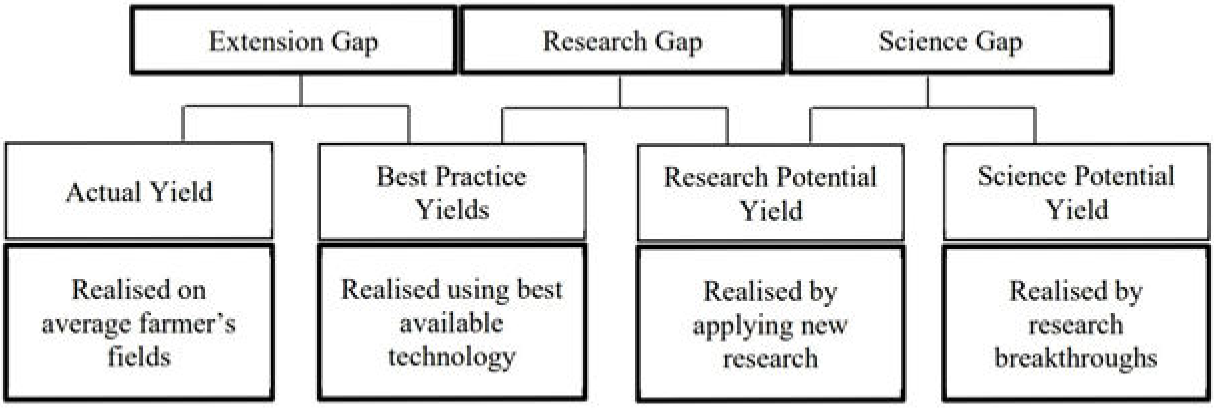

Figure 1. Agriculture study's findings

The information presented under DATES falls into the categories of quantity of variable inputs, embodied technical change, and disembodied technical change. These categories are part of the broader framework of total agricultural output growth, as depicted in figure 2.

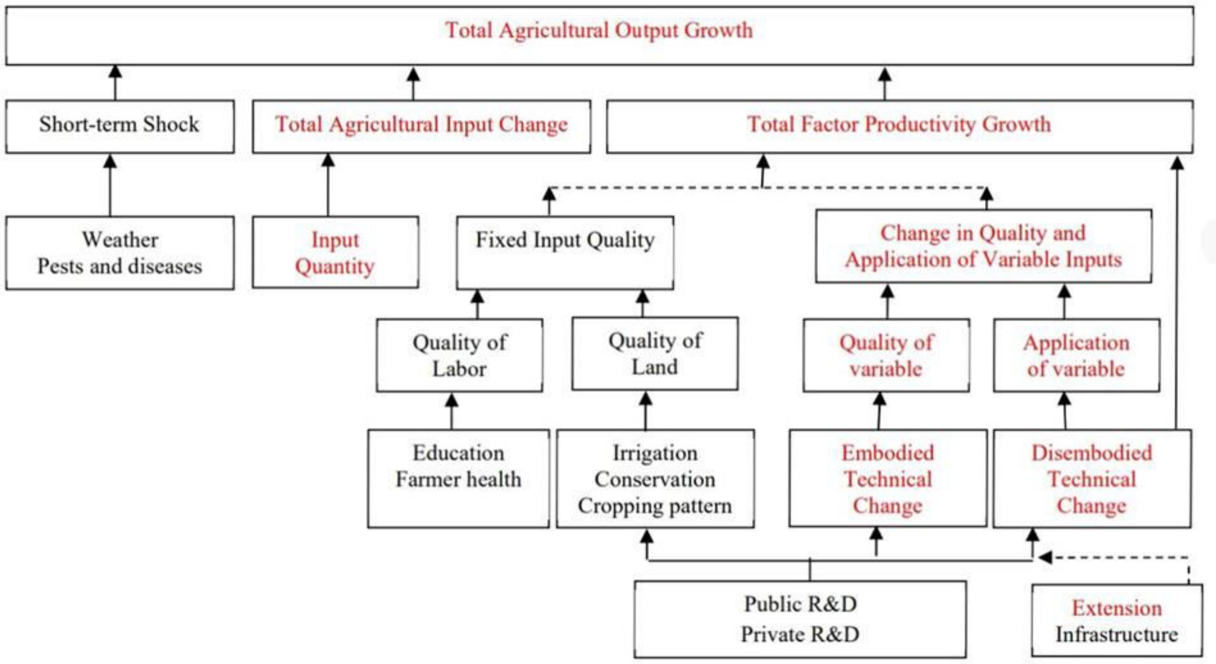

Figure 2. Total Agricultural Output Growth

Embodied technical change refers to the adoption of improved and enhanced products, such as seeds with higher yield potential or greater resistance to diseases. On the other hand, disembodied technical change involves changes in the application of variable inputs and farm management practices. Through DATES, farmers were encouraged to adopt superior products, particularly better seeds, fertilizers (both organic and inorganic), and plant protection chemicals. Additionally, farmers were provided with information on the appropriate products, quantities, methods, and timing for the use of variable inputs. These combined recommendations resulted in an increase in total factor productivity, which is defined as the output realized per unit of input. To assess the impact of the intervention on the major crops in the area, we focused our analysis exclusively on farmers who had grown at least one of the two main crops paddy and cotton during the baseline period and in either one or both of the subsequent periods (midline and endline). Out of the 600 households initially considered, 50 households (32 from the treatment group and 18 from the control group) did not

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meet this criterion and were therefore excluded from the analysis. For the remaining 550 households, we matched the baseline characteristics of the treatment and control groups across 13 parameters. Table presents the summary statistics of the key variables, categorized by the experimental groups.

Panel B: Caste Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
General Caste	0.30	0.44	-015***
	(.03)	(0.03)	(0.04)
Scheduled Caste	0.08	0.09	0.00
	(0.02)	(0.02)	(0.02)
Scheduled Tribe	0.24	0.10	0.14***
	(0.03)	(0.02)	(0.03)
Other Backward Caste	0.38	0.37	0.01
	(0.03)	(0.03)	(0.04)
Panel C: Land Ownership Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
Marginal	0.19	0.16	0.03
	(0.02)	(0.02)	(0.03)
Small	0.24	0.21	0.04
	(0.03)	(0.02)	(0.04)
Semi-Medium	0.27	0.27	0
	(.03)	(0.03)	(0.04)
Medium	0.22	0.27	-0.05
	(0.02)	(0.03)	(0.04)
Large	0.07	0.09	-0.02
	(0.02)	(0.02)	(0.02)
Panel D: Asset Index Categories			
	(1) Control	(2) Treatment	(1) Vs (2)
Asset Index 1	0.23	0.18	0.05
	(0.03)	(0.02)	(0.03)
Asset Index 2	0.20	0.17	0.03
	(0.02)	(0.02)	(0.03)
Asset Index 3	0.18	0.22	-0.04
	(0.02)	(0.03)	(0.03)
Asset index 4	0.17	0.22	-0.05
	(0.02)	(0.03)	(0.03)
Asset index 5	0.21	0.20	0.01
	(0.02)	(0.02)	(0.03)
N	282	268	

Table 1 provides crop-wise details on the number of farmers cultivating paddy and cotton, the average area under cultivation, and the percentage of farmers with access to irrigation.

Panel A shows the number of farmers who cultivated each crop at the specified survey points. Panel B details the average area (in acres) under cultivation for each crop at those points, and Panel C presents the percentage of farmers who had access to irrigation for each crop. Farmers who did not cultivate these crops at baseline were excluded from the analysis. Paddy, being the dominant crop in the region, had consistently higher numbers of farmers cultivating it across all three time periods compared to cotton. Additionally, farmers devoted more land to paddy on average. Nearly all paddy farmers had assured access to irrigation in all three periods, while fewer than 40% of cotton farmers had access to irrigation.

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	Comtrol Farmers			Treatment Farmers		
Panel A: Number of farmers						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	178	173	147	199	197	146
Cotton	146	140	128	119	112	111
Panel B: Average area under cultivation (acre)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	7	8	9	8	9	10
Cotton	6	8	10	6	8	9
Panel C: Access to Irrigation (% of farmers)						
	Baseline	Midline	Endline	Baseline	Midline	Endline
Paddy	100	100	98	99	99	100
Cotton	28	37	31	19	38	22

Table 2 presents the average values and standard deviations for yields, revenues, costs, and net returns for paddy and cotton crops across the three time periods.

Analysis of Cost Components Affected by the Intervention

To identify the cost components influenced by the project, we conducted Difference-in-Differences (DiD) regressions for the primary cost components. For paddy farmers, the midline data shows a significant increase in seed costs and a notable decrease in irrigation costs due to the intervention. The increase in seed costs can be attributed to the project's recommendation to use 'younger' paddy saplings, which are more expensive. On the other hand, the reduction in irrigation costs is likely due to the adoption of improved water management practices, which led to reduced water usage and, consequently, lower labor costs for irrigation. By the endline, treatment farmers reported a significant reduction in costs related to plowing and weeding for paddy compared to the baseline. For cotton farmers, the regression coefficients for interculture costs were statistically significant and negative, indicating a reduction in these costs. The decrease in weeding and interculture expenses is further explained later in the section.

II. LITERATURE SURVEY

The topic of hybrid agricultural information delivery systems is gaining increasing attention as a means to improve the sustainability of agriculture, particularly in developing countries like India. The literature on agricultural information delivery has evolved significantly, with earlier studies focusing primarily on traditional extension services and more recent work exploring the integration of digital technologies to enhance the reach and effectiveness of these services.

2.1 Traditional Agricultural Extension Services

Historically, agricultural extension services have played a crucial role in disseminating knowledge to farmers. These services typically involve government or NGO-led initiatives where extension workers provide face-to-face guidance on agricultural practices, pest management, crop selection, and other farming-related activities. According to Van den Ban and Hawkins (1996), traditional extension services have been effective in improving agricultural productivity, but they often suffer from limitations such as inadequate reach, lack of timely information, and limited resources. Studies by Feder, Just, and Zilberman (1985) have also pointed out the inefficiencies in traditional extension services, particularly in reaching smallholder and marginalized farmers.

2.2 The Rise of Digital Agriculture

With the advent of digital technology, there has been a growing interest in using information and communication technology (ICT) to enhance agricultural extension services. Digital platforms such as mobile apps, SMS alerts, and social media have emerged as powerful tools for delivering agricultural information. For example, Aker (2011) discusses how mobile phones have revolutionized information dissemination in agriculture by providing timely market

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information, weather forecasts, and farming tips directly to farmers. Similarly, Mittal and Mehar (2016) highlight the impact of mobile-based agricultural advisory services in India, where farmers receive crop management advice through SMS and voice messages. These studies demonstrate that digital tools can significantly improve the accessibility and timeliness of agricultural information, leading to better decision-making by farmers.

2.3 The Hybrid Approach

While digital platforms have proven effective, they are not without challenges. Issues such as digital literacy, access to mobile phones, and internet connectivity can limit their effectiveness, particularly among smallholder and marginalized farmers. This has led to the development of hybrid agricultural information delivery systems that combine traditional extension services with digital tools. The hybrid approach aims to leverage the strengths of both methods—ensuring that farmers receive information in a format that is both accessible and actionable. The concept of hybrid systems has been explored in various studies. Davis and Sulaiman (2014) discuss the potential of combining face-to-face interactions with digital tools to create a more robust and inclusive agricultural information delivery system. They argue that while digital tools can enhance reach and efficiency, the human element provided by traditional extension services is crucial for building trust and ensuring the adoption of new practices. A study by Meera, Jhamtani, and Rao (2004) also supports this view, suggesting that hybrid models are more effective in addressing the diverse needs of farmers, particularly in regions with varying levels of access to technology.

2.4 Experimental Insights from India

In the Indian context, several experimental studies have been conducted to evaluate the effectiveness of hybrid agricultural information delivery systems. For instance, Anand and Narayan (2019) conducted a field experiment in rural India, where they tested a hybrid model combining traditional extension services with a mobile-based advisory platform. Their findings indicated that the hybrid model significantly improved farmers' knowledge and adoption of sustainable practices compared to either traditional or digital methods alone. Similarly, a study by Gandhi, Veeraraghavan, and Toyama (2009) in rural India demonstrated that a hybrid approach led to better resource management and higher agricultural productivity. The literature suggests that hybrid agricultural information delivery systems offer a promising approach to enhancing the sustainability of agriculture, particularly in developing countries like India. By combining the strengths of traditional extension services with digital tools, these systems can improve the accessibility, timeliness, and relevance of agricultural information. However, successful implementation requires careful consideration of local contexts, including digital literacy, access to technology, and the specific needs of farmers. As the literature indicates, the hybrid approach has the potential to significantly improve agricultural sustainability, but further research and experimentation are needed to refine these systems and ensure their effectiveness across diverse agricultural landscapes.

III. IMPACT ON NET RETURNS

At baseline, cotton farmers in the treatment group experienced negative average net returns, meaning that when the imputed value of family labor was factored into cost calculations, their costs exceeded their revenues. Although the average returns for treatment farmers were higher at midline compared to control farmers, the DiD analysis indicated no statistically significant increase in returns due to the intervention at this stage. By the endline, however, treatment farmers saw higher returns than control farmers for both paddy and cotton. The DiD analysis supports these findings, showing that the project led to a 78% increase in returns for paddy farmers and a 221% increase for cotton farmers after two years of intervention. This significant rise in returns is attributed to the combined effects of increased revenues and reduced costs for treatment farmers at endline.

Impact of the Intervention on Efficiency of Agricultural Operations

To validate the observed changes in yields, costs, and returns, we compared the technical efficiency scores of treatment and control farmers across the three time periods. As discussed in section 5.3, technical efficiency scores represent how close farmers are to the frontier of efficient input-to-output transformation. A higher technical efficiency score indicates that a farmer is closer to this frontier, reflecting greater efficiency in converting inputs into outputs.presents the distribution of treatment and control farmers across various categories based on their technical efficiency scores for paddy and cotton across the three time periods.

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IV. TECHNOLOGY TRANSFER FOR A HYBRID AGRICULTURAL INFORMATION DELIVERY SYSTEM

Technology transfer is a critical process in the development and implementation of a Hybrid Agricultural Information Delivery System (HAIDS) aimed at enhancing sustainability in agriculture. The successful transfer of this technology involves not only the dissemination of technical knowledge but also the adaptation and integration of the technology into the local agricultural ecosystem.

4.1 Identifying Appropriate Technologies

The first step in technology transfer for HAIDS is identifying the appropriate technologies that can be integrated into the system. This includes both traditional agricultural practices and modern digital tools. Traditional practices may involve established extension services, community meetings, and field demonstrations. On the digital side, the technology could include mobile applications, SMS-based advisory services, social media platforms, and cloud-based data analytics. The selection of technologies should be based on their relevance, accessibility, and usability for the target population of farmers.

4.2 Adaptation to Local Contexts

One of the key challenges in technology transfer is ensuring that the technologies are adapted to the local context. This involves understanding the specific needs, challenges, and capabilities of the farmers who will be using the system. For instance, in regions with low digital literacy, the technology might need to include more user-friendly interfaces or voice-based advisory services. Similarly, in areas with limited internet connectivity, offline capabilities or SMS-based systems could be more effective. The adaptation process also involves tailoring the agricultural information to local crops, weather patterns, and farming practices.

4.3 Building Local Capacity

Effective technology transfer requires building the capacity of local stakeholders to use and maintain the system. This includes training farmers, extension workers, and local agribusinesses on how to use the digital tools and how to integrate them with traditional practices. Capacity-building efforts should also focus on developing local expertise in managing and updating the system, ensuring its sustainability over time. Workshops, training sessions, and demonstration projects are essential components of this capacity-building process.

4.4 Collaboration and Partnerships

The successful transfer of HAIDS technology often requires collaboration between various stakeholders, including government agencies, non-governmental organizations (NGOs), private sector companies, and research institutions. Government agencies can play a crucial role in providing infrastructure and policy support, while NGOs and research institutions can offer expertise in technology adaptation and capacity building. Private sector companies, particularly those involved in telecommunications and software development, can provide the necessary digital tools and platforms.

V. MONITORING AND EVALUATION

To ensure the effectiveness of the technology transfer, it is essential to establish a robust monitoring and evaluation (M&E) framework. This framework should track the adoption and usage of the HAIDS, assess its impact on agricultural productivity and sustainability, and identify areas for improvement. Regular feedback from farmers and other users is critical to refining the system and addressing any challenges that arise.

5.1 Scaling and Sustainability

Once the HAIDS has been successfully transferred and implemented on a small scale, the next step is to scale the system to reach a broader audience. Scaling efforts should focus on expanding the reach of the system while maintaining its relevance and effectiveness. This may involve developing new partnerships, securing additional funding, and continuously updating the technology to keep pace with changing needs and conditions. Sustainability is a key consideration in this phase, requiring ongoing support from local stakeholders and continuous improvements to the system.

Although agricultural information delivery is not widely utilized as a tool for enhancing productivity in India, our study demonstrates its significant potential to improve agricultural productivity in an ecologically and financially sustainable manner. We examined the outcomes of the DATES project, an agricultural information delivery initiative that combined traditional extension methods with modern information and communications technology to provide best-practice

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guidance to 300 farmers cultivating paddy and cotton.The results of the DATES intervention indicate that, given the substantial yield gaps in various crops across India, significant yield improvements can be achieved through the effective dissemination of agricultural practice information. The intervention also highlights that better farm management practices can enhance the technical efficiency of farming enterprises. Importantly, these productivity gains do not come with increased costs for farmers, nor do they harm the environment. By providing precise information on the application of agricultural inputs, the intervention not only increased the effectiveness of these inputs but also optimized the quantities required. This optimization led to reduced production costs and minimized the adverse environmental impacts associated with excessive input use. Our findings align with the work of Pagani, Sawyer, & Mallarino (2013) on optimal nutrient rates for crops, showing that reducing fertilizer quantities does not necessarily lead to yield declines in areas where intensive agriculture is practiced. These results are particularly noteworthy given that studies like Fishman et al. (2017) found no significant impact of agricultural information delivery on fertilizer use.The DATES intervention demonstrated that significant improvements in both productivity and profitability are achievable through the provision of best-practice information to farmers. However, our findings are specific to irrigated areas, crops with substantial input investments, and crops highly susceptible to pest attacks. To fully understand the robustness of these outcomes, similar interventions should be tested in different agro-ecological zones, with other crops, and on a larger scale.

VI. CONCLUSIONS

The successful technology transfer of a Hybrid Agricultural Information Delivery System (HAIDS) for enhancing sustainability in Indian agriculture is a multifaceted process that requires careful consideration of local contexts, capacity building, and stakeholder collaboration. By integrating traditional agricultural practices with modern digital tools, HAIDS offers a comprehensive solution to the challenges faced by farmers in accessing timely and relevant information. The adaptation of technology to meet the specific needs of different regions and communities is crucial for ensuring its effectiveness and widespread adoption. Building local capacity through training and ongoing support is essential for the sustainable implementation of HAIDS. Collaboration among government agencies, NGOs, the private sector, and research institutions is vital for providing the necessary resources, infrastructure, and expertise to support the technology transfer process. Monitoring and evaluation play a critical role in refining the system and ensuring its continuous improvement. Ultimately, the successful transfer and scaling of HAIDS can lead to significant advancements in agricultural productivity and sustainability in India. By empowering farmers with the right information at the right time, this hybrid approach can contribute to more resilient agricultural practices, better resource management, and improved livelihoods for farming communities.

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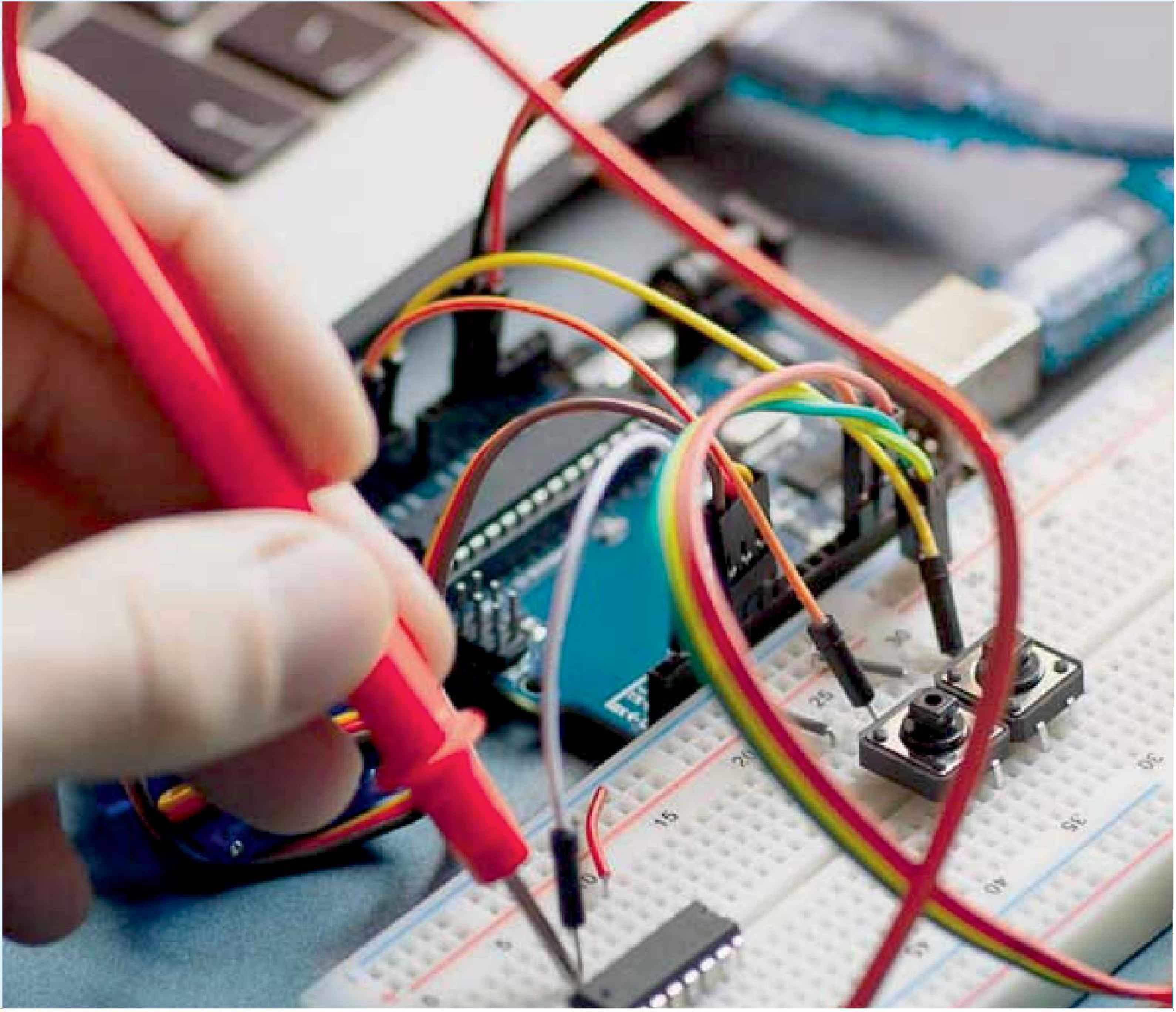

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