

# Integrated Design of Technology-Based Marketplaces for Agriculture in Developing Countries

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**Abstract:** This paper maintains that technology-based marketplaces present significant opportunities for buyers and sellers of agricultural products in developing countries. In order to realize these opportunities marketplace engineers in academia and industry need to develop a design framework which takes into account the complex, intertwined structure of formal and informal market institutions, trading rules and technological delivery mechanisms. The implied research agenda is illustrated with cases of functioning technology-based agricultural marketplaces in the Philippines and Ethiopia. An integrated bottom-up approach to design focusing on behaviour and emergence is discussed.

**Keywords:** ICTs for development, intermediation, market design, market institutions, HCI.

## 1. Digital Problems and Opportunities

Information and communications technologies (ICTs) have been hailed as the engine for future economic growth throughout the world. Unfortunately, the adoption and proliferation of network industries in developing countries has remained scarce, creating what is known as the “digital divide” ([1]). There are many immediate explanations for the observed differences in ICT penetration and uptake between the advanced industrial economies of the North and the less developed economies of the South. The reasons include but are not limited to the high fixed cost of fibre optical networks and the low technological literacy among populations in the developing world.

Even though it is normally framed as an access problem, the “digital divide” is essentially a problem of equitable economic development, predicated by the relationship between ICTs and the productive base of economies at different stages of industrialisation [2]. In advanced industrial countries with high levels of accumulated physical and human capital information technology has been used for the creation of fast moving “knowledge” economies. These are economies dominated by the service sector where the shortening lifespan of new products mandates the reduction of costs for research, development, and organization of production. The extensive use of information technology has managed to deliver cost savings precisely in these areas. The economies of less and least developed countries are not faced with the same pre-production cost-cutting predicament because of their reliance on labour and natural resources as drivers for growth. The “equitization” of innovation has not worked in favour of knowledge industries in developing countries and has contributed to a considerable “knowledge gap” [3]. Much-hoped for leapfrogging opportunities have remained scarce and awkward [4]. Therefore, in the immediate term “new” industries are unlikely to match traditional ones as a source of income in developing economies. In fact, the agricultural sector offers some of the few efficient and pro-poor

development options [5]. As it happens, this is precisely the sector where trade -- local or international -- remains an undeniable sticking point.

Fink and Kenny [6] propose the paradigm of “digital opportunity” as an alternative to the currently pervasive notions of the “digital divide” and “knowledge gap”. The shift in language indicates a move away from presenting the growing gap in access to ICTs as a development challenge in and of itself. There are reasons to be optimistic about the potential of new generations of mobile phones and low-cost computing devices to reduce the access gap [7]. The challenge of realizing digital opportunities lies in the creation of functional income-generating ICT uses for the developing country context. The creation of (dynamic) electronic and/or mobile marketplaces for agricultural produce (staple or high value) could contribute significantly to increased rural incomes and to broad-based poverty and inequality reduction. To mobilize enterprise efficiently and benefit traders, researchers and practitioners need to design marketplaces with three main facets of the problem in mind: formal and informal institutions, market mechanisms and trading technology.

## **2. Motivating Cases**

Dynamic technology-based marketplaces such as ‘eBay’ have become widely used in advanced industrial economies, and they are quickly expanding in countries with high rates of industrialization such as China and India ([8]). Still, their application to agricultural markets in countries with low level of industrialization is still in its infancy. To demonstrate their viability and the revenue and coordination gains they create, we describe two exploratory cases from the Philippines and Ethiopia. Case materials were collected from available secondary sources. In Section 2.3 we refer to these cases in order to illustrate the research questions that need to be covered by the design of technology-based marketplaces.

### *2.1 - Electronic Marketplace for Farmers: ‘B2Bpricenow’, the Philippines*

The Philippines is a lower-middle income country with per capita national income in the ballpark of \$100 per month [9]. Thirty-eight percent of the population lives in rural areas where poverty remains a deeply rooted phenomenon [9]. In the period 1985–2000 urban poverty decreased by over 10%, while rural poverty stagnated at levels around 45% [10]. Indicators for the telecommunications sector such as mobile telephony coverage (80%) and adult literacy rate (93%) are quite strong [9]. Access to mobile telephones (387 subscribers per 1000 people, [9]) greatly surpasses access to fixed lines (41 subscribers per 1000 people, [9]) and use of mobile phones is similarly skewed. Detailed case studies and media reports ([11], [12]) indicate use for SMS exceeds use for voice calls on the scale of 20:1.

This is the environment in which ‘B2Bpricenow’, an electronic marketplace catering to farmers, operates. Its mission is to connect farmers and to provide them with a venue for trading their goods. The founder, Edgardo Herbosa observed the considerable information asymmetries in the agricultural market: “farmers produce crops that they soon realize have no potential buyers” [13]. He decided to put together a Web site addressing this problem by providing farmers with immediate information about the demand for their produce.

‘B2Bpricenow’ allows agricultural producers to bypass traditional intermediaries and to reduce costs by monitoring market prices without travelling. The marketplace collects offers to sell and requests to buy, and posts the information in specified product categories. The contact information of the buyers and sellers is easily available and in case they are interested in the possibility of trade both parties are able to pursue it. ‘B2Bpricenow’ aims to offer more than a listing service. Features include: price change alerts, SMS and WAP phone accessibility, setting virtual meetings, negotiating online, closing legally binding contracts and processing transaction documents, and paying online via affiliated banks.

Among these services the significance of the feature offering mobile access to price quotes has been recognized by the World Bank as one of the 30 winners in the Development Marketplace Competition held in January 2002. As mobile phone use in the Philippines continues to increase the significance of the service cannot be overstated. Its early success does not make 'B2Bpricenow' the perfect marketplace. Problems related to on-line payments and credibility risk are as significant as in other online marketplaces. More than anything else, the popularity of 'B2Bpricenow' underscores the need for up-to-date market information in the agricultural sector in the Philippines. It also demonstrates the viability of electronic/mobile marketplaces as a mode for delivering such information.

## *2.2 - Internet Auctions for "Fair Trade" Coffee: ECAFE, Ethiopia*

Unlike the Philippines, Ethiopia is a low-income economy with low life expectancy and education levels. Taking into account these indicators the global human development index ranks Ethiopia 170<sup>th</sup> out of 177 countries [14]. The per capita national income is less than \$1 a day and the adult literacy rate is 42%. The majority of the population (84%) lives in rural areas where poverty remains a deeply rooted phenomenon [15]. Poverty in Ethiopia is phrased in terms of food security and supply rather than income level. Growing population, deteriorating farm land and draughts are contributing factors to poverty [16]. The telecommunications sector is dominated by a large public monopoly and services are limited. On average per 1000 people there are 2 personal computers and 1 Internet user [15]. Despite low levels of ICT access Ethiopia has seen initiatives aiming to deliver digital benefits ranging from electronic content to payments ([17], [18]).

In July 2005 Ethiopian coffee growers were able to gain access to a market of premium coffee roasters worldwide by holding an Internet coffee auction - the 'Q-Auction'. The auction was realized by the ECAFE foundation with the support of US and Ethiopian non-government and professional organizations such as Agricultural Cooperative Development International (ACDI), Volunteers in Overseas Cooperative Assistance (VOCA), the Coffee Quality Institute (CQI), Coffee Corps, the Specialty Coffee Association of America, the Ethiopian Coffee & Tea Authorities and the Ethiopian Coffee Unions.

CQI who have the responsibility of organizing the 'Q-Auction' proceedings describe it as an alternative to traditional coffee markets "that guarantees quality through industry-accepted cupping procedures, verified by Q-Graders" [19]. The auction offers full-container loads of mainstream specialty coffee and as such is targeted at the primary coffee buyers, as opposed to buyers of boutique and rare coffees. The 'Q-Auction' also boasts a dependable and transparent ascending auction mechanism, consistent with current business practice.

The prices achieved in the first auction for Ethiopian coffees averaged US\$ 3.22 per pound i.e. more than double the world market price of US\$ 1.30 per pound. The income generated for Ethiopian cooperative farmers was more than US\$ 187,800 ([20], [19]). 2% of revenues were earmarked for community development projects by the 'Q-Auction' organizers, whose aim is not only to increase growers cash receipts, but also ensure the sustainable supply of quality coffee to benefit the entire specialty coffee industry.

The highest bid at the Ethiopian coffee auction (US\$ 6.50/lb) was placed by the US company Green Mountain Coffee Roasters. The second highest bid (US\$ 5.50/lb) came from a US cooperative bidding group ([20], [19]). As a result of the fragmented buyers' side of the market, small roasters have not been able to participate in the international market for full-size coffee lots. An ingenious rule allowing coalition bidding in the 'Q-Auction' permits small roasters to aggregate demands to bid on full-size lots and compete against companies with greater market share, thereby increasing revenues for the producers.

The case of the 'Q-Auction' shows that technology-based marketplaces are possible even in adverse environments with low ICT access and well established alternative markets.

The viability of the auction was achieved by the active involvement of intermediaries, standardization efforts and responsive bidding rules.

### *2.3 - Illustrating the Design Agenda*

Both of these cases present scenarios where technology-based marketplaces have improved results for agricultural producers. However, under the divergent socio-economic conditions of Ethiopia and the Philippines two different exchange modes in terms of organization, standardization of the transactions, and technology use have proved successful.

Although it provides additional services, the main function of 'B2BPricenow' is as a venue for an otherwise decentralized market. Buyers and sellers find each other's contact information at the Web site but verification of product quality, negotiation of terms and trades are carried out largely elsewhere (e.g. in person, on the phone). The technological and skills barrier to marketplace entrance is minimal. The single requirement is an Internet connection or a mobile phone. Due to the symbolic nature of mobile communication even basic literacy is not a necessary requirement. The 'Q-Auction' presents an entirely different scenario. It is heavily institutionalized by the intermediation services of CQI. The institute actively organizes not only both sides of the market by ensuring the quality of the coffee and the credibility of the buyers, but it also designs and sets the auction mechanism. The technology presents essential infrastructure for the strategic interaction during the auction and its use requires a degree of competence, as does the bidding decision itself.

With reference to these two cases we propose that the integrated agenda for the design of technology-based marketplaces focuses on the following four research areas:

- Optimal level of intermediation & involvement of formal institutions. Would 'B2BPricenow' customers benefit by providing more extensive intermediation services (e.g. delivery infrastructure, warranties, security)? Would 'Q-Auction' participants benefit from reduced intermediation resulting in broader access to the marketplace?
- Provision of incentives for emergence of beneficial social norms. Do 'B2BPricenow' users have sufficient incentives to share personal information? Do coffee growers participating in the 'Q-Auction' have incentives to develop community norms such as supporting each other's efforts and sharing information about best practices?
- Optimal market mechanism with respect to allocation efficiency and revenue maximization. Could the one-to-one take-it-or-leave-it bargaining which dominates 'B2BPricenow' be improved on by the introduction of competition between buyers/sellers in the form of online auctions? Does the 'Q-Auction' format provide an efficient allocation? Does it maximize revenues? What are the benefits and dangers of coalition bidding? How should it be facilitated?
- User-friendly information technology. Technological mediation and control of market behaviour. Can a technology imposing smaller skills requirements on the 'B2BPricenow' user be designed? Would an extensive migration of the services from the Internet to mobile be preferable to the status quo? Does the technology implementing the 'Q-Auction' influence the realized allocation and payment outcomes? How can this technology be improved so that the market performs at its best?

In the following sections we proceed with a brief discussion of the theoretical issues related to the above agenda. In Section 3 we focus on the components of the design space for technology-based marketplaces and the significant phenomenon of emergence. In Section 4 we discuss market microstructure in the shape of formal and informal institutions. In Section 5 we cover in more detail the design of market mechanisms. In Section 6 we focus on the mediating role and the design of technology.

### **3. Behaviour, Design & Emergence Phenomena in Technology-Based Markets**

In theoretical economics market behaviour and design are recognized as two sides of the same coin. Studies in market behaviour analyze how given a set of stable institutions, traders respond to the incentives incorporated in the market rules, decide on optimal strategies and thereby determine clearing prices and quantities. Market design deals with the inverse problem of calculating a set of optimal market rules given that bidders behave in an incentive compatible and individually rational manner. See [21], [22] for textbook introductions to the field. As it was illustrated by the cases above, the problem of designing technology-based marketplaces for the agricultural sector in developing countries is complicated by at least two factors which are not explicitly addressed by economic theory. The first factor is the existence of stable (formal or informal) institutions which assure compliance to market and non-market rules and assist participants with the formation of truthful expectations. Formal institutions in developing countries tend to be weak and fragile ([23]) therefore it is problematic to treat markets in isolation from them. Informal institutions are by definition fluid and evolving and thereby influence market performance. The second factor which remains unaccounted for in economic theory is the impact of technology. Control on behaviour, yielded by technological implementations and low levels of technological literacy among users, is capable of distorting market signals and outcomes.

Due to these two complicating factors the design space for technology-based marketplaces in developing country settings must be expanded to include the set of possible institutions and technologies. This extended design problem is difficult to state using abstract mathematical tools, more difficult to solve and probably impossible to solve at a level of concreteness useful to practitioners and implementers. We propose that academics focus on developing a more holistic, integrated approach, taking into account economic theory, theories of formal and informal institutions and human-computer interaction.

Ideas of emergence and adaptation, rather than mathematical abstraction, can serve as the unifying basis of this holistic, integrated approach. Emergence is bottom-up, inductive, and dynamic while abstract design is top-down, deductive and static. In developing ICT-supported marketplaces, emergence and design should be seen as reinforcing and inextricably intertwined. Designs incorporate, reify and recreate tools, behavioural patterns and social norms which have emerged out of the practice of the productive activity of exchange. Designs also elicit responses from the communities pursuing the productive activity, which consequently adapt and reconstitute their practices. Wenger [24] argues that “the challenge of design is not a matter of getting rid of the emergent, but rather of including it and making it an opportunity.” The challenge for integrated design of technology-based marketplaces is not only to create more efficient and accessible markets on the basis of existing social institutions, bargaining methods and technology use practices, but also to allow emergence processes to guide the development of these markets.

### **4. Market Microstructure**

‘Market microstructure’, a financial market term is used to refer to the formal or informal institutions governing the market [25]. We understand as an institution a system of social rules, coordination mechanisms and operational standards that renders predictable the actions of market agents who systematically draw on it, reproduce and/or transform it.

#### *4.1 - Formal Intermediaries*

Formal intermediaries are third parties who facilitate exchanges between buyers and sellers. They can serve as explicit sides to centralized market transactions or as simple clerks in decentralized market. The adoption of ICT-enabled commerce by farmers in developing

countries can be seen as an opportunity for decentralization leading to reduced intermediation in agricultural markets and increased fairness of benefit to the end consumers and producers [7]. However, centralization through intermediaries may be essential in the uptake of electronic commerce [17]. The presence of a formal intermediary in a technology-based agricultural market and specifics of its role are significant design decisions with consequences for market performance and participants' outcomes.

The design of formal market institutions is focused on mapping a set of possible intermediation structures to the performance set of the market. If an intermediary reduces transaction efficiency, it is likely to be sidestepping and eventually disappear. In the presence of economies of scale, information asymmetries, or costs to operating or using the market mechanism, markets are in great danger of failure. In these cases intermediation can be beneficial and improve performance. The performance-enhancing functions of intermediaries include aggregating supply and/or demand, reducing asymmetries between atomic agents on one side of the market and big players on the other side, reducing operating, processing or coordination costs, providing payment and delivery services, matching buyers and sellers ([26], [27]). Formal intermediaries smooth the functioning of markets by assuring market clearing, price discovery, liquidity and immediacy. They also facilitate matching and searching, guarantee and monitor transactions. Technology-based marketplaces for agricultural products are open to both scenarios. They could give rise to substantial intermediation, as in the case of the 'Q-Auction', or they could be used for the elimination of traditional intermediaries as in the case of 'B2BPricenow'.

#### *4.2 - Informal Institutions*

The risk reduction impact of intermediaries can be achieved alternatively by the functioning of informal social institutions within the marketplace. We call informal institutions these patterns of self-organization which result from participants' behaviour but have consequences beyond their conscious or immediate intentions. For example, relational norms of cooperation and reciprocity which arise in networked exchanges are informal institutions in the marketplace because they are self-enforcing, mutually beneficial behaviours. Institutionalized behaviours such as accepted norms with regards to the sharing of personal information impact market outcomes by enabling (or not) participants in the market to trust others, to assess their intentions and to form expectations. Formal intermediaries could foster such informal institutions by providing mechanisms for the creation of reputations and transaction histories, or they could discourage them by ensuring anonymity and protecting personal information.

#### *4.3 - Design*

The design of institutions for technology-based markets is concerned with the establishment of the optimal boundaries for the market-maker and incentives for the market participants to follow set rules of conduct. As the case of the 'Q-Auction' shows, formal intermediaries such as governments, charities, professional organizations and farmers' unions can play significant roles by collecting and listing information, verifying quality, ensuring payment and drafting legally binding contracts. Similarly, informal social institutions such as traditional values and the behaviours associated with them influence market performance. An analytical understanding of the emergent and evolutionary nature of institutions, along the lines of Jessop and Nielsen [28], is instrumental to the synthetic exercise of designing technology-based marketplaces for the future. The main design challenge in this area remains avoiding the pitfalls of voluntarism (good people will pursue a feasible alternative once such is identified) and structuralism (institutional longevity excludes change).

## 5. Market Mechanism

Even though the tractability and the rationality restrictions of the mechanism design approach have been criticized [29], it has not been seriously challenged. Indeed, mechanism design methodology has been successfully implemented in practice in the creation of markets for pollution emissions, electricity and electro-magnetic spectrum. Mechanism design has a lot to contribute to the design of technology-based marketplaces. It is up to the task of providing optimal rules for the dynamic pricing and clearing of well studied markets for perishable agricultural commodities such as fish and flowers ([30], [31]). The current theoretical literature is also well poised to address issues of collusion and cooperation such as the formation of bidding rings and bidding coalitions [32]. The practices observed in the ‘Q-Auction’ case clearly point to the relevance of these concerns to development marketplaces where one side of the market is disproportionately fragmented.

Related to the literature on mechanism design is that on two-sided matching [33]. It is applicable to situations when there is considerable degree of competition on both sides of the market and participants’ primary concern is finding a trading partner with characteristics meeting a clearly stated preference (e.g. a trading partner removed by the shortest distance). As a static listing site ‘B2Bpricenow’ does not match buyers and sellers but many of the posted offers are advertised on a “first come first serve” basis. This indicates that sellers are concerned with finding a buyer and might benefit from participating in a matching mechanism. If participants are concerned with a non-traded attribute of the transaction such as the distance they have to travel for the exchange the participation in a centralized matching mechanism could address this concern without compromising the price of the transaction.

Despite the appeal of its rigor and generalizability of its results, the top-down approach of mechanism design runs contrary to our understanding of the emergence of market rules. Rather than being designed by an omniscient engineer, market mechanisms evolve naturally by responding adaptively to changes in the needs and the behaviour of their participants. Thus, the implementation of the top-down approach runs into its main problem: ensuring participation. Notably, top-down design has been successful in government sponsored applications where incumbent markets did not exist and all the interested participants had to subscribe to the newly engineered market. Due to the natural aversion of existing markets to change, it is difficult to ensure participation in an incipient alternative to a traditional marketplace. The mechanism design challenge lies in developing an understanding of how the derived theoretically optimal designs could be achieved in practice.

Within technology-based markets the engineering approach is feasible to the extent that the owners of the technology infrastructure have the authority to set the rules of the market mechanism. Still, in order to ensure the success of a new marketplace it is essential to implement rules conducive to broad-based participation. One possible approach is to look for an understanding of how mechanism rules could be adapted in response to the internal pressures of the marketplace [29]. The capacity for such adaptation will ensure the evolutionary emergence of an optimal mechanism within a functioning, popular marketplace. This bottom-up approach could have significant practical advantages in comparison to the top-down approach of mechanism design which leads to theoretically optimal but often unpopular or strategically impenetrable market mechanisms.

## 6. Technology

It is essential to recognize the impact of technology on the performance of technology-based marketplaces. Technological implementations are capable of facilitating as well as frustrating trading and the formation of social norms. Even with an optimal mechanism the market might perform sub-optimally due to its sub-optimal human-technology interaction.

For example, if the human-technology interaction at the input phase is not of sufficient quality the signals sent by the users to the market would misrepresent their preferences and intentions. Implementation also impacts the evolution of market institutions evolve. It could obscure or aggravate existing information asymmetries and risks thereby leading to the emergence of suboptimal market microstructure.

Technologies should present a good fit to the skill sets, cognitive tendencies and information literacy of user populations. Removing these constraints remains the challenge to technology designers. It has been suggested that digitalization shifts the method of communication from literate to visual [34] thereby increasing communication via symbolic systems at the expense of text and traditional literate forms. The combination of this language paradigm shift with lower ICT prices and with new technologies such as 3G and multi-media mobile services, has the potential of moving the world in the direction of higher density and quality of communication in underdeveloped areas. Establishing an integrated framework for the design of technology-based marketplaces could provide an opportunity for utilizing communication growth to the benefit of the poor and the illiterate.

## 7. Conclusions

The design of technology-based marketplaces requires a degree of understanding of the mapping from the combined design spaces of market institutions, market mechanisms and market technologies to the space of market performance which has not currently been developed. In the cases of 'B2BPricenow' and the 'Q-Auction' aspects overlooked by market designers such as formal and informal institutions and technological delivery appeared to be particularly important. Therefore, we have proposed that academics and developers include them alongside with mechanisms in an integrated holistic approach to the design of technology-based marketplaces for agriculture in developing countries.

Market design is generally understood as a top-down activity, and runs the risk of producing what the name suggests – a design, rather than a functionally adequate structure for the delivery of optimal performance. To realize the considerable potential for pro-poor benefits from the introduction of technology-based marketplaces in the agricultural sector of developing countries, we need to broaden our understanding of market design.

Firstly, the design of technology-based marketplaces needs to take into account the multiple dimensions of existing practice. The levels of formal intermediation, the strengths and weaknesses of informal market institutions and behaviours, the skills, literacy levels, and technology adoption aptitudes of the target populations should be properly studied and understood. Thus, whenever these features are market performance enhancing they could be reified. When they are not, the design should include incentives and opportunities for the development of improved institutions, behaviours and skills. Secondly, we suggest that designs should allow for adaptation. Market mechanisms and institutions evolve from the bottom up and respond to the concerns and behaviours of their participants. Therefore, we believe that their design is best addressed using methods which accommodate this process of emergence. The development of such methods is beyond the scope of the current article and the main proposed area for future academic inquiry.

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