Fit-risk in Development Projects: Role of Demonstration in Technology Adoption

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Abstract

Introduction and adoption of new technologies are an important component of development projects. Many technologies that could spur considerable increase in welfare, however, are often adopted at low rates even when donors and NGOs have invested heavily their effort in them. This paper develops a framework to analyze inefficiencies caused by fit-risk (potential users are not certain whether the technology will fit their needs, lifestyles, social feedback, or capabilities), and the role of marketing tools like demonstration in reducing fit-risk and enhancing efficiency of development projects. We find that, in the presence of fit-risk, there is always unrealized demand and resource waste. Donors who ignore fit-risk always overestimate the project value and over-subsidize the products they are promoting. We identify conditions under which introducing demonstration may help alleviating fit-risk and improve overall project values. The impact of eliminating fit-risk on the project uptake depends on the probability of fit.

Classification: D8, I3, O1, O2, O3

Keywords: technology adoption; fit-risk; demonstration; development subsidy; waste; unrealized

demand.

1. Introduction

As part of their effort to promote environmental protection and reduce poverty, international donors, non-profit organizations (NPOs) and governments have invested in the development and introduction of new technologies in developing countries. To accelerate the adoption of these technologies and because of the positive externalities they provide, they have been aggressively subsidizing and distributing them to broadly targeted populations. For instance, over the past couple of years the Cereal Systems Initiative for South Asia (CSISA) has put in substantial effort to promote agricultural technologies such as zero-tillage, laser land leveling, early sowing of wheat, etc., in South Asia's Indo-Gangetic Plains to improve cereal production growth and protect the environment. The adoption of these technologies, however, continues to be low and varies between different regions (Laxmi et al., 2007). There is a growing concern for the low rate of adoption, and thus increasing the rate of utilization of new technologies is a challenge for donors (e.g. Hanna et al., 2012; Dupas, 2014). This paper develops a conceptual framework to analyze the phenomenon of underuse of new technologies in the context of economic development and suggest marketing tools to enhance utilization and reduce waste. It borrows from a large literature in marketing that emphasizes the role of consumer fit-risk in underutilization of products and analyzes the role of marketing tools like money back guarantee (MBG) and demonstration in reducing fit-risk and enhancing efficiency (Heiman et al., 2001).[1]

The economics literature on technology adoption has investigated the adoption behavior from various aspects such as production (yield) risk (e.g. Koundouri et al., 2006; Giné & Yang, 2009), learning (e.g. Edmondson et al., 2003; Straub, 2009), reference price (e.g. Heffetz & Shayo,

[1] The use of marketing tools like MBG and demonstration to address fit-risk have been used relatively recently in the developed world, and are rare in developing countries (Zilberman et al., 2012).

2009) and network (e.g. Katz & Shapiro, 1986; Bandiera & Rasul, 2006), yet there has been much less recognition of the existence and implications of fit-risk (Zilberman et al., 2012).

Fit-risk occurs when potential adopters are not sure if the technology will fit their needs, lifestyles, social feedback, or capabilities. Fit-risk arises because of individual level idiosyncratic differences in local population; a technology may suit different individuals differently due to heterogeneity of population characteristics, skills, preferences, environments, etc. For example, persons with allergies may not find technologies involving chemical application suitable to use. Fit-risk also depends on the nature of technology and individuals who consider it. For example, adoption of tractors or vehicles for farming may depend on capability of farmers to drive. Similarly individuals with poor vision, or observation capacity may have high fit-risk regarding an integrated pest management strategy based on monitoring of pest populations.

New technologies tend to be more efficient but also add new sources of risks, and these risks may be exacerbated due to local conditions[2]. For example, high yielding seed varieties may perform very well in the presence of irrigation and other complementary inputs but may fail in their absence. Fit-risk, however, is inherently different from these other risks as it manifests at an individual level and differs across individuals within the same population in the same local environment. There may be complementarities between the other risks associated with a new technology and fit-risk; a technology with a lower overall risk may also have a lower fit-risk. In this paper we abstract away from these complementarities and assume that the net benefit from the technology takes into account the risks associated with it.

Furthermore, fit-risk is not a case of asymmetric information, because the fit of the product prior to the user experience is random, and unknown both to the user and the technology provider.

[2] We thank the anonymous reviewer for suggesting to incorporate a discussion on this.

Not recognizing fit-risk will result in a different type of inefficiency than caused by traditional price and quality risk or cases of asymmetric information.

Fit-risk is especially likely to occur with experience goods, where acceptance and utilization of the good cannot be predicted with certainty unless the user experiences it. People may learn about fit-risk through alternative instruments such as social networks or learning from others. Fit-risk may also be affected by the way a product is packaged and/or explained, etc. However, because fit-risk arises due to individual level idiosyncratic differences in local population, instruments such as social information (word of mouth), learning from others, advertisement, etc., are not sufficient to address it (Klein, 1998).

International development community has been seeking how private sector management frameworks are relevant for repositioning and practicing of NPOs (e.g. Austin, 2000; Lindenberg, 2001; Eikenberry & Kluver, 2004). The present paper aims to develop a framework to answer this question. It identifies situations where lack of consideration of fit-risk may result in suboptimal outcomes in technology provision by public and non-profit organizations, and how demonstration can improve market outcomes.

The analysis uses a simple threshold adoption model, which recognizes heterogeneity among potential adopters (e.g. Zilberman et al., 2012) to derive demand for a new technology. Only those potential adopters whose expected benefit is higher than the market price will buy it. This results in inefficient non-adoption because the expected benefit drops in the presence of fit-risk. Amongst those who buy the technology, only those for whom the technology is suitable will use it. Thus fit-risk may not only decrease technology adoption, but also generates resource waste. Ignoring fit-risk or misunderstanding the dynamics of technology demand under existence of fit-risk can lead to miscalculation of project values and potential benefits of marketing efforts in development projects. Project donors and managers may develop different policy strategies based on the level of technology fit and cost of marketing efforts. The paper analyzes when it is worth to incur costly demonstration of the technology that eliminates fit-risk, and shows that (i) the economic net benefit of costly demonstration is non-monotone in the probability of fit, and (ii) demonstration is not worthy when the probability of non-suitability of the technology is either too high or too low.

Marketers in developed countries have been using MBG and demonstration to address fit-risk. While MBG is a marketing tool that allows the consumer to receive some or all of their payment back if the purchased product does not meet her expectation and returned within a given period of time (Heiman et al., 2001), demonstration is a tool that allows the consumer to experience the product before purchase. We focus on demonstration as compared to MBG as demonstration requires lower transaction costs (in terms of processing returns, and reusing returned products) and does not require a great level of trust between sellers and buyers. Demonstration increases the precision of technology provision in development projects by revealing personal level of technology fit and potential product benefits. The marketing literature finds that demonstration reduces the potential customer's resistance and affects consumers' prior beliefs about the product (Scott, 1976; Roberts & Urban, 1988). The following examples illustrate how demonstration can help alleviating fit-risk in new technologies. Test driving of cars is a form of demonstration that helps individuals to know if a specific car appeals to them in terms of performance and convenience. The adoption of agricultural technologies such as integrated pest management (IPM), seed transplantation, zero tillage, drip irrigation, tractors, mechanized harvesters, etc., may be reduced without adequate demonstration.

The rest of the paper is planned as follows. The next section presents the model. Section 3 discusses an optimal subsidy in the presence of fit-risk. While section 4 constructs a demonstration gain function, section 5 analyzes a policy that combines demonstration and optimal subsidy to eliminate fit-risk. In section 6, we discuss some extensions of our analysis. Finally, section 7 concludes the paper.

2. Model

Suppose a donor wishes to introduce a technology that has potential to improve welfare in a developing country. Private benefits derived from the technology differ across individuals in the local population -- some people are likely to benefit more from the technology as compared to others. The technology adoption delivers social value in addition to the private benefit. The additional social value could be an environmental or health externality, philanthropic services of the donor, redistribution, etc. The technology, however, may not be suitable for all, and provides benefits only if it is suitable. Further, prior to acquiring the product, the potential beneficiaries do not know whether it would fit them. They may eventually learn about their fit after acquiring and trying it. Not knowing ex-ante whether a technology would fit an individual or not is termed as "fit-risk" in our model.

Assume that the private benefit from the technology, b, varies across the population of measure 1 with a continuous density function $f(b)$ and cumulative distribution function $F(b)$ with supports $[\underline{b}, \overline{b}]$.[3] Suppose that the probability that it fits a particular individual is q. For simplification, we assume that q is independent of b, and is known.[4] Thus q proportion of the consumers buying the product would actually use it, and $(1-q)$ of the acquired products will be

[3] In our model, "b" denotes overall perceived benefit of the technology after taking into account the quality and risks embedded in it.

[4] This assumption simplifies the analysis. We conducted an analysis for a more general case where q and b are correlated, and find that the results are qualitatively similar but the analysis becomes intractable after a point.

wasted. The expected benefit to an individual from adopting the technology is qb. In addition to the private benefit, the technology also has social value, v. The demand is determined by the mass of consumers for whom the expected benefit from acquiring the technology is larger than the unit cost. We also assume that each individual buys at most one unit of the technology. Quantity purchased, Q,

$$= \int_{b^*}^{\bar{b}} f(b)db = [1 - F(b^*)] \tag{1}$$

where b^* denotes marginal consumer indifferent between purchasing and not purchasing. We can analyze quantity purchased under different scenarios by identifying the marginal consumer. Under probability of fit q, and price, p, the marginal consumer indifferent between buying and not buying is given by $b^* = \frac{p}{q}$

$$Q(p, q) = \int_{\frac{p}{q}}^{\bar{b}} f(b)db = \left[1 - F\left(\frac{p}{q}\right)\right] \tag{2}$$

To understand the inefficiencies caused by fit-risk, we compare the above demand with the potential demand if there was no fit-risk. In the absence of fit-risk, the expected benefit of the technology to an individual is b. The marginal consumer indifferent between buying and not buying the technology, thus, is given by $b^* = p$. Since the technology fits to q proportion of the population, potential demand in the absence of fit-risk, $\bar{Q}$, is given by

$$\bar{Q} = q \int_{p}^{\bar{b}} f(b)db = q\big(1 - F(p)\big) \tag{3}$$

The difference between the potential demand in the absence of fit-risk and in its presence is given by

$$\bar{Q} - Q(p, q) = q\big(1 - F(p)\big) - \left(1 - F\left(\frac{p}{q}\right)\right) \tag{4}$$

$$= q \int_{p}^{\bar{b}} f(b)db - \int_{\frac{p}{q}}^{\bar{b}} f(b)db \tag{5}$$

which can be expressed as

$$= q \int_{p}^{\frac{p}{q}} f(b)db - (1-q) \int_{\frac{p}{q}}^{\bar{b}} f(b)db \qquad (6)$$

The first term in the above expression represents potentially additional demand that would arise from eliminating fit-risk, which we term as "unrealized demand". The second term represents reduction in demand as a result of avoiding "waste" due to non-use. These terms are defined below.

Unrealized demand is defined as the additional mass of consumers for whom the expected benefit becomes higher than the price when fit-risk is eliminated.

$$URD\ (p, q) = q \left[F\left(\frac{p}{q}\right) - F(p)\right] = q \int_{p}^{\frac{p}{q}} f(b)db \qquad (7)$$

Waste is defined as the quantity wasted due to non-use after purchase. Since $(1-q)$ proportion of the population does not use the technology after purchasing, waste in the presence of fit-risk is given by

$$RW(p, q) = (1-q)\left(1 - F\left(\frac{p}{q}\right)\right) = (1-q) \int_{\frac{p}{q}}^{\bar{b}} f(b)db \qquad (8)$$

Fit-risk, thus, gives rise to two distortions in demand. Unrealized demand results in underutilization of a potentially beneficial technology as some potential adopters who would have adopted the technology in the absence of fit-risk do not adopt it. Second, a subset of those who acquire the technology do not use it or do not benefit from it because it does not fit their specific requirements, resulting in waste. Figure 1 graphically illustrates these concepts. Assume b to be uniformly distributed over $[\underline{b}, \bar{b}]$. The quantity purchased under fit-risk is given by the sum of regions B and D. Region B represents waste since consumers in this region do not use the product. Potential adopters belonging to region C do not acquire the technology even though it has potential to provide net positive benefits, i.e., it represents unrealized demand. The net effect on demand is given by the difference in the areas of region B and region C, and the aggregate resource misallocation is represented by the sum of regions B and C.

[Figure 1 here]

Let welfare be defined as the net surplus generated by the technology, which is the net benefits from the technology and can be measured as the sum of the private value to the consumers and social value less the cost of the technology. Recall that the benefits will be reaped by only q proportion of the population whereas the costs are incurred for the entire mass of population acquiring the technology. Given probability of fit q, social value v, and per unit cost of technology c, welfare in the presence of fit-risk is given by

$$sw_0(p,q) = \int_{\frac{p}{q}}^{\bar{b}}[q(b+v)-c]f(b)db \tag{9}$$

Similarly, potential welfare in the absence of fit-risk is given by

$$sw_1(p,q) = q\int_{p}^{\bar{b}}(b+v-c)f(b)db \tag{10}$$

The loss in welfare due to fit-risk is given by

$$sw_1(p,q) - sw_0(p,q) = \int_{p}^{\bar{b}} q(b+v-c)f(b)db - \int_{\frac{p}{q}}^{\bar{b}}(q(b+v)-c)f(b)db \tag{11}$$

which can be expressed as

$$= \underbrace{\mathrm{q}\int_{p}^{\frac{p}{\mathrm{q}}}(b+v-c)f(b)db}_{loss\ from\ URD} + \underbrace{(1-\mathrm{q})\int_{\frac{p}{\mathrm{q}}}^{\bar{b}} cf(b)\,db}_{loss\ from\ RW} \tag{12}$$

Observe the above two terms represent the value of the loss associated with two distortions in demand caused by fit-risk, and thus correspond to the two terms given in equations (6).

In Proposition 1, we examine how changes in price and likelihood of fit affect the two sources of distortion in demand, viz., unrealized demand and waste. In the next section, we discuss how the existence of fit-risk affects donors' decision on price via providing a subsidy.

Proposition 1: *For given* p, q, *and* $0 < q < 1$,

(i) *Elimination of fit-risk increases (decreases) demand if unrealized demand is greater* *(less) than waste;*

(ii) *In the presence of fit-risk, there always exist unrealized demand for* $0 < q < 1$, *and waste for* $\beta < q < 1$ *where* $\beta \equiv \frac{p}{F^{-1}(1)}$;

(iii) *Waste is decreasing in p and non-monotonic in q;*

(iv) *Unrealized demand is increasing in p if* $f(p/q) \geq q f(p)$;

(v) *A sufficient condition for the unrealized demand to be decreasing in q is that the elasticity of distribution function (EDF) >1, where* $EDF \equiv \frac{bf(b)}{F(b)}$;

(vi) *If the benefit* b *is distributed uniformly over* $[\underline{b}, \overline{b}]$, *the unrealized demand is decreasing in q and increasing in* p *for* $\beta < q < 1$.

Part (i) of Proposition 1 states that elimination of fit-risk may increase demand by reducing unrealized demand but may decrease demand due to reduction in waste. The net effect is determined by the trade-off between these two opposite effects. An interesting implication of this result is that if for some reason performance is measured by the quantity of sale, it may not be desirable to eliminate fit-risk. Part (ii) tells us that existence of fit-risk results in two distortions in demand: (a) inefficient non-adoption or unrealized demand because the expected value of benefit drops in the presence of fit- risk, and (b) waste, as acquisition may occur even when technology is not suitable. Parts (iii) and (iv), together, show that a subsidy policy (via decreasing price) may reduce unrealized demand but would increase waste. At lower prices, consumers would be more inclined to buy the technology. But since $(1 - q)$ proportion of the acquired technology will not be utilized due to mis-fit, waste would also be higher as more of it is acquired. The non-monotonic relationship between resource waste and q is another interesting result. It might seem intuitive that waste should be monotonically decreasing in q

as better fit should imply less waste of resources. With an increase in q, however, there are two opposite forces affecting resource waste. One, as q increases the technology fits to a greater proportion of the population reducing the waste due to misfit. But with an increase in q, the demand also increases, having an effect of increasing the waste. The net effect of an increase in q would depend on the relative strengths of these two effects. At sufficiently low levels of fit, the demand effect dominates the fitness effect and waste is increasing in q. When q becomes sufficiently large, the fitness effect dominates the demand effect, and the waste is decreasing in q.

Part (iv) of Proposition 1 further implies that the impact of price to expand unrealized adoption depends not only on population value distribution but also on level of technology fit. Part (v) indicates that if CDF of private benefit distribution increases rapidly relative to the change of private benefit b, unrealized demand decreases as likelihood of fit increases. This result might seem intuitive because if more people value technology (i.e., more density or higher b), they tend to acquire technology more as likelihood of fit increases, thus unrealized demand decreases. Part (vi) presents these results for a uniform distribution.

Figure 2 plots unrealized demand and resource waste across different fit probability, q, assuming b to be uniformly distributed over $[0, 1]$, and assigning numerical values of 0.3 to the price of the technology p. It can be readily seen from the Figure that at low probability of fit, the size of unrealized demand is greater than the size of resource waste. However, for sufficiently high level of probability of fit, the size of waste dominates the size of unrealized demand. Thus for sufficiently high q, elimination of fit-risk may lead to a decrease in demand.

[Figure 2 here]

3. Optimal Subsidy and Project Value

Recall the technology has an externality v associated with it. Project donors may want to promote the technology beyond its market demand due to the positive externality associated with it. Thus they consider providing a subsidy to lower the price of acquisition.

Suppose that project donors want to maximize welfare from their projects. From equation (9), given probability of fit q, social value v, and per unit cost of technology c, donors' objective welfare function at price p is given by

$$\underset{p}{Max}\, sw_0 = \int_{\frac{p}{q}}^{\bar{b}} [q(b+v) - c] f(b) db \tag{13}$$

The socially optimal price maximizes the above objective function. Differentiating sw_0 with respect to p, and using fundamental theorem of calculus, socially optimal price is given by

$$\hat{p}_0 = c - vq \tag{14}$$

implying a socially optimal subsidy

$$\hat{s}_0 = vq \tag{15}$$

since subsidy $s = c - p$. A subscript 0 denotes value of the variables in the presence of fit-risk, and a superscript ˆ denotes optimal value of variables. A subsidy internalizes the social value, v associated with the technology, and since the technology fits to only q proportion of the population, the subsidy is accordingly adjusted to vq.

If, however, individuals knew whether the technology fits them or not, i.e., there is no fit-risk, donors objective function follows from equation (10):

$$\underset{p}{Max}\, sw_1 = q \int_{p}^{\bar{b}} (b + v - c) f(b) db \tag{16}$$

where subscript 1 denotes the value of the variables in the absence of fit-risk. Proceeding in the same manner as above, maximizing sw_1 with respect to p, we obtain the optimal subsidy $\hat{s}_1$ in the absence of fit-risk.

$$\hat{s}_1 = v \tag{17}$$

The loss of welfare due to fit-risk, after implementation of an optimal subsidy is given by

$$\widehat{sw}_1 - \widehat{sw}_0 = q\int_{c-v}^{\bar{b}} (b+v-c)f(b)db - \int_{\frac{c-vq}{q}}^{\bar{b}} [q(b+v)-c]f(b)db \tag{18}$$

which can be expressed as

$$= q\int_{c-v}^{\frac{c-vq}{q}} (b+v-c)f(b)db + (1-q)\int_{\frac{c-vq}{q}}^{\bar{b}} cf(b)db \tag{19}$$

Proposition 2:

(i) *Fit-risk reduces optimal level of subsidy;*

(ii) *A subsidy increases demand, but also increases waste associated with fit-risk;*

(iii) *The loss of welfare due to fit-risk after implementing an optimal subsidy is given by*

$$= q\int_{c-v}^{\frac{c-vq}{q}} (b+v-c)f(b)db + (1-q)\int_{\frac{c-vq}{q}}^{\bar{b}} cf(b)db \tag{20}$$

Part (i) of Proposition 2 is intuitive. Since in the presence of fit-risk, expected social value drops to qv from v, the optimal level of subsidy in the presence of fit-risk is smaller than the optimal subsidy when there is no fit-risk. If donors ignore this leakage in potential welfare, they may over-subsidize. Part (ii) suggests that a subsidy policy increases quantity demanded through not only reducing unrealized demand, but also generating waste. An increase in waste has a welfare reducing effect. Thus even when donors take into account fit-risk while deciding the optimal subsidy they cannot prevent waste due to mis-fit. Since society bears the cost of wasted products, the overall welfare may decrease if donors do not take an action to address it. The expression for loss in welfare due to fit-risk after implementing an optimal subsidy policy is provided in Part (iii). It suggests that there is a potential to increase welfare through elimination of fit-risk. Donors, however, need to compare the cost of marketing effort to eliminate fit-risk with its potential benefit.

Demonstration is one such marketing tool that helps in reducing fit-risk. The next section presents gains from demonstration and section 6 analyzes when it is optimal to undertake demonstration taking into account its costs.

Figures 3 illustrates demand and resource waste generated as a function of probability of fit, q, assuming $c = 0.3, v = 0.2$, b is distributed uniformly over $[\underline{b}\ \overline{b}]$, and a subsidy as perceived optimal for the two cases — presence and absence of fit-risk. Figures 4 shows the social welfare (project value) under the subsidy levels and assumptions of figures 3.

[Figure 3 here]

[Figure 4 here]

4. Demonstration Gain Function

Donors realize that there is fit-risk, which causes welfare loss. They may take measures to reduce it. It will be worthwhile to correct the distortions caused by fit-risk, if the cost of correction is smaller than the gain. Demonstration is a marketing tool that reduces fit-risk by enabling individuals to find out whether the technology fits them so they are more likely to make the right decision. The effect of demonstration may depend on duration, effort and intensity of demonstration. Demonstration is perfect when it eliminates all fit-risk and individuals get fully informed about fit. For simplicity we assume perfect demonstration in this paper.

A.1: *Perfect demonstration: demonstration eliminates all fit-risk.*

To first focus on gains from demonstration, we ignore cost of demonstration and also suppress social value v in this section. To compare gains from demonstration with its cost, we will introduce demonstration cost and bring back social value in the next section. To understand the role of demonstration in eliminating fit-risk and comparing its effect across different levels of q, we construct *Demonstration Gain Function.* Demonstration results in better allocation of technology among targeted population via the two channels discussed before -- by generating additional adopters who would not have acquired the technology due to fit-risk, and by preventing waste due to mismatch. The efficiency gains from demonstration, thus, comprise of the net additional value generated due to increased adoption, and the value of resources that are prevented from being wasted. These gains are expressed in the demonstration gain function provided in Proposition 3.

Let us also clarify that in our set up, the role of demonstration is not to increase the fitness of the technology.[5] Demonstration helps to reveal to the potential adopters its suitability to them so that they buy the technology only if it matches them individually.

Proposition 3. *Assume A.1*

The Demonstration Gain Function is given by

$$G(q) = \begin{cases} q\int_{p}^{\frac{p}{q}}(b-c)f(b)db + (1-q)\int_{\frac{p}{q}}^{\bar{b}} cf(b)\,db & if\ \beta \le q \le 1 \\ q\int_{p}^{\bar{b}}(b-c)f(b)db & if\ 0 \le q < \beta \end{cases} \tag{21}$$

$$where\ \beta \equiv \frac{p}{F^{-1}(1)}\ ;$$

(i) *The Demonstration Gain Function is an increasing function of q for* $0 \le q < \beta$ *and a strictly concave function of q for* $\beta \le q \le 1$.

(ii) $G(q)$ *is positive for* $0 < q < 1$, *and* $\lim_{q\to 0} G(q) = \lim_{q\to 1} G(q) = 0$.

(iii) *G(q) has a maximum between* $\beta \le q \le 1$.

The two equations for the demonstration gain function on the right-hand side of (21) for

[5] Demonstration can increase technology fitness by learning, and our model may be extended to incorporate that. In this case, the gain from demonstration will be higher than those in equation (21).

different ranges of q can be explained as follows. For $\beta \leq q \leq 1$, the demonstration results in gains through both channels – by inducing more demand and also by preventing waste. For sufficiently low levels of $0 \leq q < \beta$, the market demand in the absence of demonstration is zero. Since at zero demand, there is no waste of resources, demonstration does not prevent any waste through this channel. Demonstration results in efficiency gains only through inducing positive demand from consumers for whom the technology fits.

Recall the non-monotonic relationship between q and waste due to difference between acquisition and usage (Proposition 1, part (iii)). Proposition 3 further builds on this relationship. It shows that if the technology is a complete mis-fit ($q = 0$) or a perfect fit ($q = 1$), demonstration does not help. However, in the interior values of q, demonstration improves welfare.

A visual presentation of a demonstration gain function appears in Figure 5. In the Figure, the difference between the gain from demonstration (the curve consisting of filled dots) and the waste due to fit-risk (the curve consisting of empty triangles) is due to the additional adoption (acquire and use) because of demonstration. Notice that the gains from demonstration are higher at internal values of fit as compared to the extremes. If q approaches one, the technology fits everybody. Since there is no fit-risk, there is no additional information gain from demonstration. If q approaches zero, the technology does not fit anyone, the market demand approaches zero as well. Again there is no gain from demonstration if the technology does not fit local population and is not demanded by them.

[Figure 5 here]

5. Implementing Demonstration with Subsidy

In this section we resume social value v and also introduce cost of demonstration. Active donors or policy designers may consider combining both subsidy and demonstration strategies for their development projects. Donor's optimization problem can be formulated as a two-step decision problem in which the donor chooses an optimal level of demonstration in the first step, and chooses an optimal subsidy in the second step, given the first step demonstration level to maximize welfare (project value). We further assume that demonstration is a binary variable that can take values 0, 1, and level of subsidy is a continuous variable. Denote D as a binary variable that takes value one if demonstration is used (D_1); zero if demonstration is not used (D_0). Following Heiman et al. (2001), we assume that the cost of demonstration E is a fixed cost and is constant. For example, costs of demonstration can be thought of sending a demonstrator to a region to explain the product and facilitate its trial amongst the population. Other examples include setting up a trial room/space for people to try the product, having a few trial pieces of the new product called testers. In all these examples, demonstration costs are fixed. Donor's optimization problem can be termed as a discrete-continuous decision problem, where she maximizes project value, SW

$$\max SW = \max_{D_1, D_0}\{(\max_{s} sw_1(s, D_1) - E),\ (\max_{s} sw_0(s, D_0))\} \tag{22}$$

Using recursive induction, the donors first solve for the optimal level of subsidy under each case $(D_1$ and $D_0)$, and then the optimal D is determined by comparing net welfare gains under demonstration and no demonstration.

Let $s_i(D_i), i = 0,1,$ denote optimal subsidy in the second step**.** Notice that the case of demonstration $D = 1$, corresponds to a situation where fit-risk is eliminated, or absence of fit-risk, and $D = 0$, corresponds to the presence of fit-risk. We have already solved for optimal subsidies for the two cases in Section 3. From equations (15) and (17), the optimal subsidies are given by

$$s_1(D_1) = v \tag{23}$$

$$s_0(D_0) = qv \tag{24}$$

implying optimal prices to be

$$p_i(D_i) = \begin{cases} c - v, & if\ D = D_1 \\ c - vq, & if\ D = D_0 \end{cases} \tag{25}$$

Plugging the optimal subsidies obtained in the second step into the first step of the optimization problem,

$$SW(s_1(D_1)) = q\int_{c-v}^{\overline{b}}(b+v-c)f(b)db - E \tag{26}$$

$$SW(s_0(D_0)) = \int_{\frac{c-vq}{q}}^{\overline{b}}[q(b+v)-c)]f(b)db \tag{27}$$

The donors would choose demonstration only if $SW(s_1\ (D_1)) \geq SW(s_0\ (D_0))$, otherwise choose no demonstration. Rearranging terms demonstration would be chosen if

$$\begin{cases} q\int_{c-v}^{\frac{c-vq}{q}}(b+v-c)f(b)db + (1-q)\int_{\frac{c-vq}{q}}^{\overline{b}}cf(b)db \geq E & if\ \tau \leq q \leq 1 \\ q\int_{c-v}^{\overline{b}}(b+v-c)f(b)db \geq E & if\ 0 \leq q < \tau \end{cases} \tag{28}$$

$$where,, \tau \equiv \frac{c}{F^{-1}(1)+v}$$

Note the left hand side of the above equation is the same as $G(q)$ defined in (21) with social value v and an appropriate subsidy level. This implies that if $G(q) - E \geq 0$, implementing demonstration with subsidy v improves the efficiency of a project and achieves higher welfare. The roots of (28) would determine the lower bound, $q_{l,}$ and the upper bound q_u of the range of q for which demonstration would be optimal.

Proposition 4: *Under A.1, social value v, and demonstration cost* $0 < E < Gmax$, *where*

$$Gmax \equiv \max_{q} G(q)$$

(i) *There exist upper bound q_u and lower bound q_l of q, such that demonstration improves welfare for* $0 < q_l \leq q \leq q_u < 1$*;*

(ii) the upper bound q_u $(lower\ bound\ q_l)$ is decreasing (increasing) in demonstration costs E ;

[Figure 6 here]

A visual presentation of a demonstration gain function assuming $c = 0.3, v = 0.2$, an optimal subsidy, and an arbitrary demonstration cost $E = 0.04$ appears in Figure 6. In the Figure demonstration improves welfare if q lies in the interior of two points where the demonstration gain function (filled dots) and the demonstration cost (dashed line) intersect, i.e., q_u and q_l. If the demonstration cost is sufficiently low such that the net gain from demonstration is positive, then demonstration with an optimal level of subsidy would lead to higher welfare as compared to an outcome when only subsidy is employed as a policy tool. It is also important to note that demonstration may actually reduce demand but increases efficiency by reducing waste.

6. Extension

In section 5 we assumed demonstration cost to be constant and considered demonstration as a binary decision problem. A generalization would be that demonstration is a continuous variable and cost of demonstration is increasing in the intensity of demonstration. Suppose cost of demonstration, $E(.)$, has both fixed and variable components. For example, $E(D) = \overline{E} + e(D)$, where D denotes fraction of population covered by demonstration, $\overline{E}$ is fixed cost of demonstration, e.g., setting up a showroom, and $e'(D) \geq 0$ is marginal cost of demonstration. Here $E'(D) \geq 0$, i.e., demonstration costs are (weakly) increasing in the fraction of population that gets informed. We can think of many interesting outcomes of this generalization.

If targeted populations are scattered across different villages and demonstration costs increase per village covered then a project manager may consider partial coverage of villages. In this case, the manger may apply demonstration only to those villages whose expected gain from demonstration is greater than the cost of demonstration.

An alternative formulation could be that the project manager knows private benefit b_i of each individual in the target population. In this formulation, project manager would apply individual demonstration up to the marginal individual i whose marginal benefit from demonstration equals the marginal cost of demonstration. This may have implications for equity and result in unequal distribution of benefits from new technologies, as individuals with higher private benefit would be selected for demonstration.

In yet another formulation, the project manager does not know private benefit b nor likelihood of fit q, then the manger implements the level of partial demonstration such that the expected marginal benefit from demonstration equals to the marginal cost of demonstration.

7. Conclusion

This paper attempts to introduce fit-risk in the development context and investigates potential mistakes that donors can make by ignoring it. Our analysis finds that in the presence of fit-risk there is always unrealized demand and waste. Ignoring fit-risk results in miscalculation of project values. A subsidy policy may increase demand but may also increase waste. Marketing tools such as demonstration can be used to reduce fit-risk and improve precision of technology provision in development projects. It increases efficiency by providing a better match between individuals and the product, it, however, does not necessarily increase market demand. When demonstration is costly, demonstration use may be inefficient if the probability of fit among the targeted population is either very low or very high. Policy implications of our results are that while promoting new technologies, development donors, governments, and NGOs should take into account fit-risk and take measures to reduce it. Demonstration should be introduced when it is not too expensive. The governments may invest in reducing cost of demonstration by providing required infrastructure. This will save precious resources.

The paper has used a simple stylized model to emphasize the role of fit-risk and demonstration in technology adoption. We analyzed optimal levels of subsidy and the decision on implementing demonstration given predetermined level of technology fit and distribution of private benefit from the technology adoption. Future research may estimate fit-risk of different technologies and to what extent the nature of the technology affects its fit-risk.

We also assumed that demonstration is perfect, i.e., it eliminates all uncertainty. Sometimes, the effect of demonstration may not be immediate since people take time to realize the suitability of the new technology, e.g., computer languages or software. It is also possible that even after demonstration, people are unsure of the suitability of the product. Under imperfect demonstration, demonstration will still reduce fit-risk but gains from demonstration may be lower. In such cases combining demonstration with another marketing tool such as money back guarantee may be useful. Future research can expand the analysis to include alternative demonstration strategies that vary in their costs and effectiveness and other marketing tools that have not been emphasized in the development context.

The conceptual framework presented here, however, contributes to the use of evaluation, design, and marketing strategies in development practice and technology diffusion. We hope that recognition of fit-risk opens a new avenue for empirical research. Quantifying the effectiveness of marketing mechanisms that aim to reduce fit-risk in different development project settings is an important empirical challenge for development donors, governments and NPOs. Future research should also assess the benefits and costs of demonstration and other mechanisms to address fit-risk, and utilize it in the introduction of resource conserving, environmentally friendly technologies. Experiments can be conducted to design demonstration strategies.

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Reference

Austin, J. E. (2000). Strategic collaboration between nonprofits and business. Nonprofit and Voluntary Sector Quarterly, 29(suppl 1), 69-97.

Bandiera, O., & Rasul, I. (2006). Social networks and technology adoption in northern mozambique*. The Economic Journal, 116(514), 869-902.

Dupas, P. (2014). Short‐Run Subsidies and Long‐Run Adoption of New Health Products: Evidence From a Field Experiment. Econometrica, 82(1), 197-228.

Edmondson, A. C., Winslow, A. B., Bohmer, R. M., & Pisano, G. P. (2003). Learning how and learning what: Effects of tacit and codified knowledge on performance improvement following technology adoption. Decision Sciences, 34(2), 197-224.

Eikenberry, A. M., & Kluver, J. D. (2004). The marketization of the nonprofit sector: civil society at risk?. Public administration review, 64(2), 132-140.

Giné, X., & Yang, D. (2009). Insurance, credit, and technology adoption: Field experimental evidencefrom Malawi. Journal of development Economics, 89(1), 1-11.

Hanna, R., Duflo, E., & Greenstone, M. (2012). Up in smoke: the influence of household behavior on the long-run impact of improved cooking stoves (No. w18033). National Bureau of Economic Research.

Heffetz, O., & Shayo, M. (2009). How Large Are Non-Budget-Constraint Effects of Prices on Demand?. American Economic Journal: Applied Economics, 1(4), 170-199.

Heiman, A., McWilliams, B., & Zilberman, D. (2001). Demonstrations and money-back guarantees: Market mechanisms to reduce uncertainty. Journal of Business Research, 54(1), 71-84.

Katz, M. L., & Shapiro, C. (1986). Technology adoption in the presence of network externalities. The journal of political economy, 822-841.

Klein, L. R. (1998). Evaluating the potential of interactive media through a new lens: Search versus experience goods. Journal of business research, 41(3), 195-203.

Koundouri, P., Nauges, C., & Tzouvelekas, V. (2006). Technology adoption under production uncertainty: theory and application to irrigation technology. American Journal of Agricultural Economics, 88(3), 657-670.

Laxmi, V., Erenstein, O., & Gupta, R. K. (2007). Impact of zero tillage in India's rice-wheat systems (No. 56093). CIMMYT: International Maize and Wheat Improvement Center. http://ageconsearch.umn.edu/bitstream/56093/2/zeroTill_india.pdf

Lindenberg, M. (2001). Are we at the cutting edge or the blunt edge?: Improving NGO organizational performance with private and public sector strategic management frameworks. Nonprofit management and leadership, 11(3), 247-270.

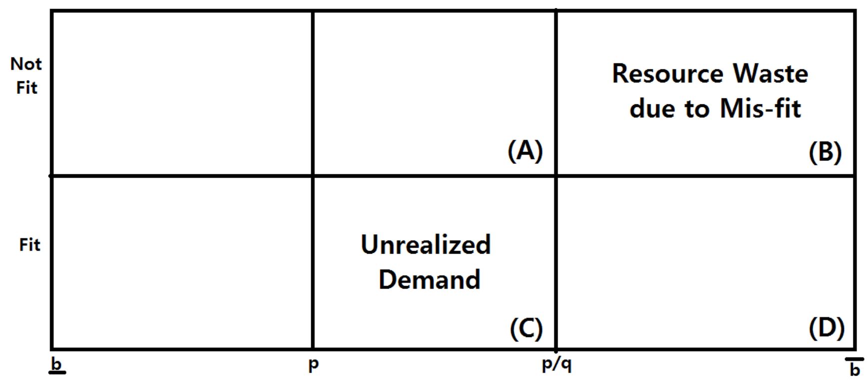
Roberts, J. H., & Urban, G. L. (1988). Modeling multiattribute utility, risk, and belief dynamics for new consumer durable brand choice. Management Science, 34(2), 167-185.

Scott, C. A. (1976). The effects of trial and incentives on repeat purchase behavior. Journal of Marketing Research, 263-269.

Straub, E. T. (2009). Understanding technology adoption: Theory and future directions for informal learning. Review of Educational Research, 79(2), 625-649.

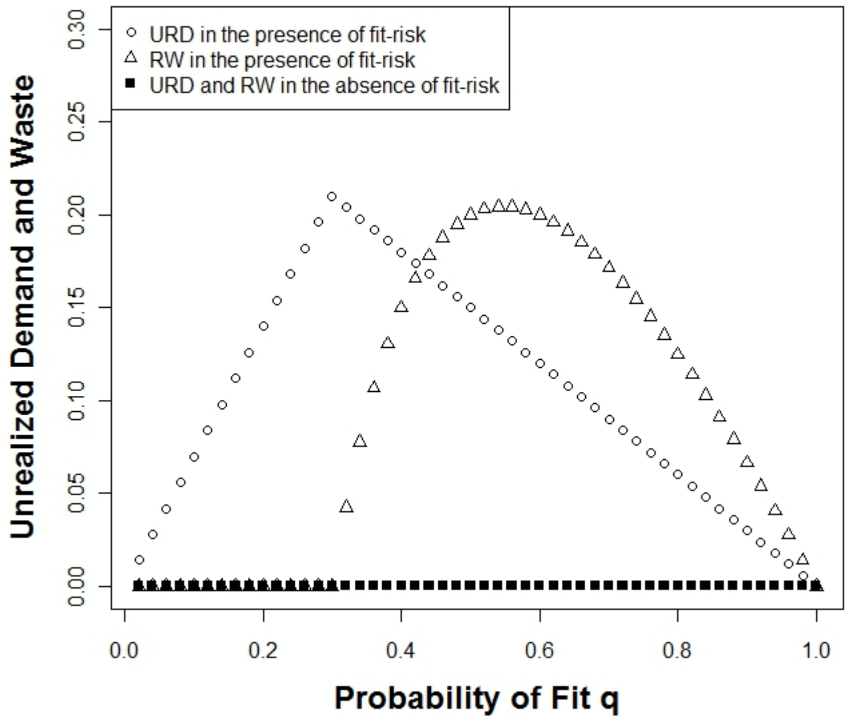
Zilberman, D., Zhao, J., & Heiman, A. (2012). Adoption versus adaptation, with emphasis on climate change. Annu. Rev. Resour. Econ., 4(1), 27-53.

Figure 1. Sources of Inefficiency due to Fit-risk



Notes: If there is no fit uncertainty, the quantity purchased is given by the sum of regions (C) and (D). Under the existence of fit-risk, on the other hand, the quantity purchased is the sum of regions (B) and (D). The technology quantity in region (B) represents resource waste and the quantity in the region (C) denotes unrealized demand.

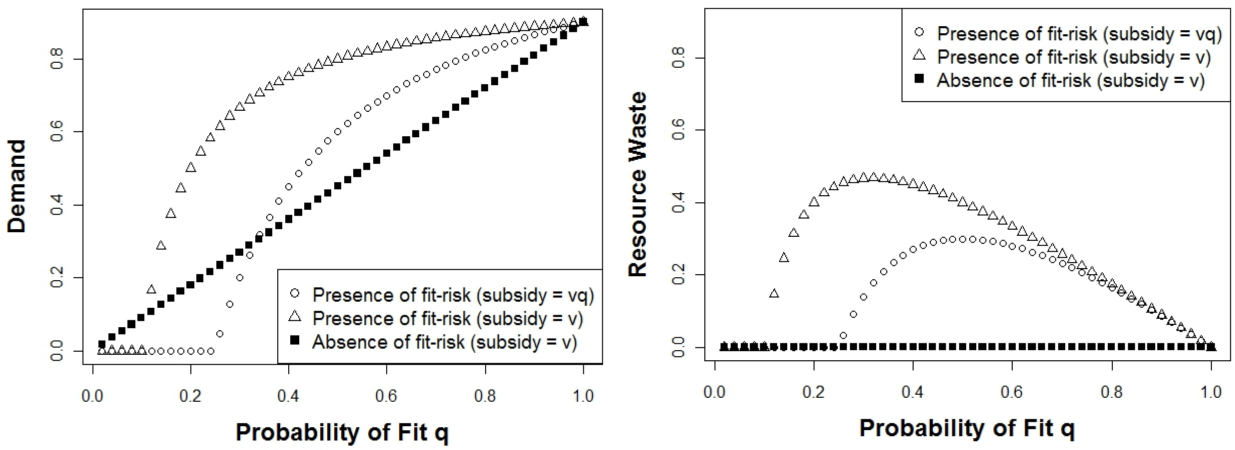
Figure 2 Unrealized Demand (URD) and Resource Waste (RW)



Notes: Plot with $p = 0.3, b \sim unif\ [0,1]$ The empty dotted curve represents unrealized demand and the curve with empty triangles depicts resource waste as a function of q. The curve with filled squares illustrate zero unrealized demand and zero waste in the absence of fit-risk. If probability of fit is low, the size of unrealized demand may be greater than the size of resource waste while the size of waste may dominate the size of unrealized demand for sufficiently high level of probability of fit. This may result in a decrease of demand after eliminating fit-risk in the latter case.

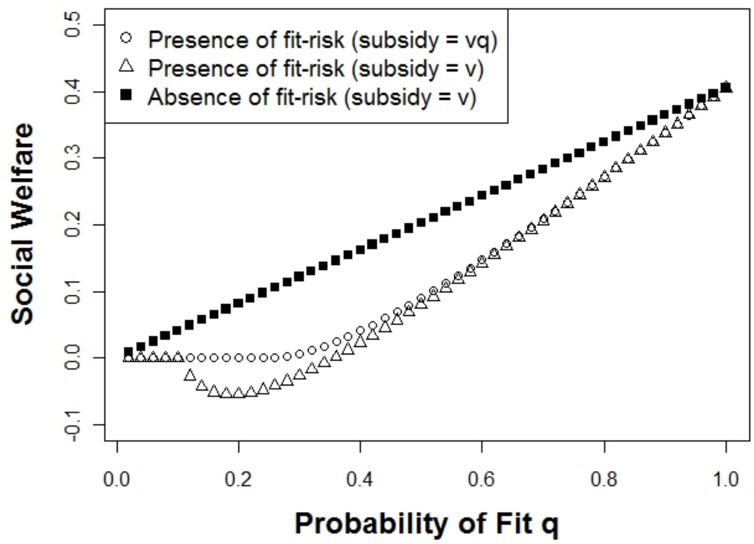
Figure 3 Demand (a) and Waste (b)

(a) (b)



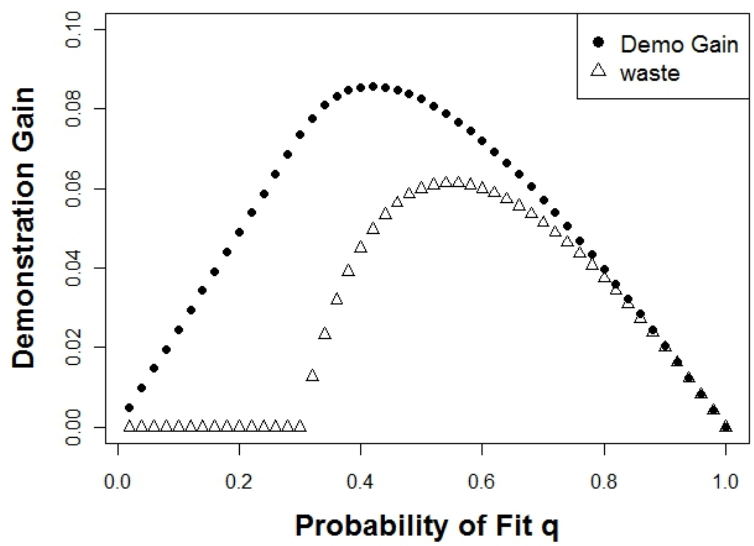
Notes: Plot with $c = 0.3, v = 0.2, b \sim unif\ [0,1]$ The empty dotted curves depict the demand in Figure 3 (a), and waste in Figure 3 (b) under the case where a subsidy = vq is offered by donors. The demand and waste with a subsidy = v is depicted by empty triangle curves. The filled squares curves illustrate the demand and zero waste in the absence of fit-risk with a corresponding subsidy s = v.

Figure 4. Welfare from Development Projects



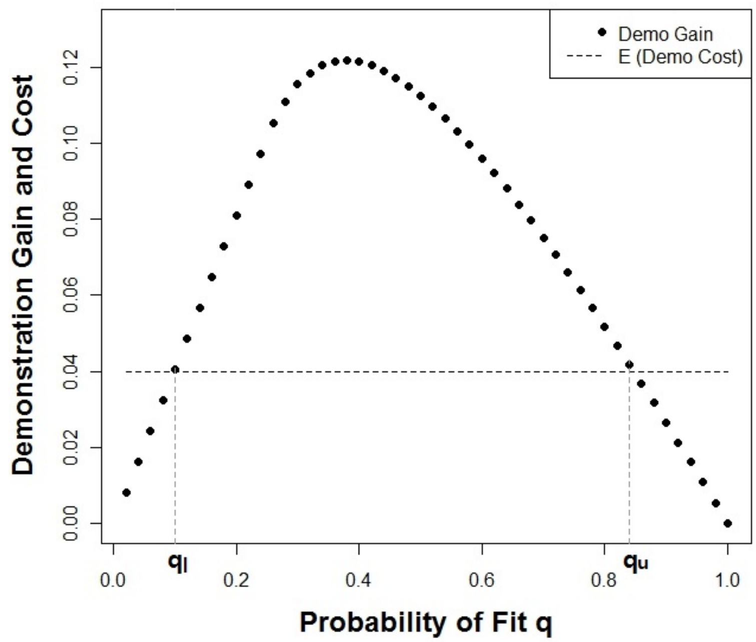
Notes: Plot with $c = 0.3, v = 0.2, b \sim unif\ [0,1]$. The curve with filled squares depicts welfare in the absence of the fit-risk with a subsidy s = v. The curves consisting of empty dots and empty triangles depict welfare in the presence of fit-risk, with subsidy $s = vq$, and $s = v$, respectively.

Figure 5. Demonstration Gain Function



Note: Plot with $p = c = 0.3, b \sim unif\ [0,1]$. The difference between the gain from eliminating fit-risk (filled dots) and waste due to fit-risk (empty triangles) is due to the additional adoption (acquisition and use) from unrealized demand.

Figure 6. Demonstration Gain and Cost



Note: Plot with $= 0.3, v = 0.2, s = vq, b \sim unif\ [0,1]\ E = 0.04$ Two points where the demonstration gain function (filled dots) and the cost of demonstration (dashed line) intersect indicate the lower bound and upper bounds of q, such that demonstration improves welfare.

Appendix

Proof of Proposition 1:

i) Follows trivially from equation (6).

ii) $URD\,(p,q) = q\int_{p}^{\frac{p}{q}} f(b)db > 0$ for $0 < q < 1,\ p < \bar{b}$.

It is reasonable to assume that the price p is smaller than the highest possible benefit $\bar{b}$. In the presence of fit-risk, resource waste is generated only when there is positive demand.

$$RW(p,q) = (1-q)\int_{\frac{p}{q}}^{\bar{b}} f(b)db > 0 \text{ only if } \frac{p}{q} < \bar{b},\ i.e., q > \frac{p}{\bar{b}}\ or\ q > \frac{p}{F^{-1}(1)} \equiv \beta.$$

iii)

$$\frac{\partial RW}{\partial p} = -\frac{(1-q)}{q} f\left(\frac{p}{q}\right) < 0$$

$$\frac{\partial RW}{\partial q} = -\int_{\frac{p}{q}}^{\bar{b}} f(b)db + (1-q)\frac{p}{q^2} f(\frac{p}{q})$$

It can be seen $\lim_{q\to 1}\frac{\partial RW}{\partial q} = -\int_{\frac{p}{q}}^{\bar{b}} f(b)db < 0$; $\lim_{q\to\beta}\frac{\partial RW}{\partial q} = (1-\beta)f(\beta)\left(\frac{\bar{b}^2}{p}\right) > 0$. Since RW is continuous function on $\beta < q < 1$, is negative in the neighbourhood of $q = 1$, and positive in the neighbourbood of $q = \beta$.

iv) $\frac{dURD}{dp} = f\left(\frac{p}{q}\right) - qf(p) \geq (<)\ 0\ iff\ f\left(\frac{p}{q}\right) \geq (<)\ qf(p).$

v)

$$\frac{dURD}{dq} = F\left(\frac{p}{q}\right) - \frac{\partial F\left(\frac{p}{q}\right)}{\partial\left(\frac{p}{q}\right)}.\frac{p}{q} - F(p)$$

$$\frac{dURD}{dq} < 0\ if\ \ F(p/q) - \frac{(p/q)\partial F(p/q)}{\partial(p/q)} < F(p).$$

A sufficient condition for the above inequality to hold is $\frac{bf(b)}{F(b)} > 1$ for all b.

vi) Let b be distributed uniformly over [$\underline{b}$ $\overline{b}$], for $0 < q \leq \beta$, quantity demand is zero under fit-risk. Therefore unrealized demand can be expressed as

$$URD\ (p, q) = q \int_{p}^{\overline{b}} f(b)db = \frac{q}{\overline{b} - \underline{b}}(\overline{b} - p)$$

$$\frac{\partial URD}{\partial q} = \frac{(\overline{b} - p)}{\overline{b} - \underline{b}} > 0, \frac{\partial URD}{\partial p} = \frac{-1}{\overline{b} - \underline{b}} < 0$$

For $\beta < q < 1$, quantity demand is positive and unrealized demand is

$$URD\ (p, q) = q \int_{p}^{\frac{p}{q}} f(b)db = \frac{q}{\overline{b} - \underline{b}}\left(\frac{p}{q} - p\right)$$

$$\frac{\partial \mathrm{URD}}{\partial \mathrm{q}} = -\frac{p}{(\overline{b} - \underline{b})} < 0\,, \frac{\partial \mathrm{URD}}{\partial \mathrm{p}} = \frac{1}{(\overline{b} - \underline{b})}(1 - q) > 0.$$

Proof of Proposition 2:

i) Follows directly from the equation (15) and (17); $\widehat{s_0} = vq < \hat{s}_1 = v$ for $0 < q < 1$.

ii) Substituting p= $c - s$ into the demand Q in equation (2), we have

$$\mathrm{Q(s, q)} = \int_{\frac{\mathrm{c-s}}{q}}^{\overline{b}} f(b)db$$

$$\frac{\partial \mathrm{Q}}{\partial s} = \frac{1}{q} f\left(\frac{\mathrm{c-s}}{q}\right) > 0 \text{ for } 0 < q < 1.$$

Substituting p= $c - s$ into the RW in equation (8), we have

$$RW(s, q) = (1 - q) \int_{\frac{\mathrm{c-s}}{q}}^{\overline{b}} f(b)db$$

$$\frac{\partial \mathrm{RW}}{\partial \mathrm{s}} = \frac{(1-\mathrm{q})}{q} f\left(\frac{\mathrm{c-s}}{q}\right) > 0 \text{ for } \frac{c-s}{F^{-1}(1)} < q < 1.$$

iii) Loss in welfare is given by the difference between project values in the absence and presence of fit-risk (after incorporating optimal subsidies) and can be expressed as

$$= q\int_{c-v}^{\bar{b}}(b+v-c)f(b)db - \int_{\frac{c-vq}{q}}^{\bar{b}}[q(b+v)-c]f(b)db$$

$$= q\int_{c-v}^{\frac{c-vq}{q}}(b+v)f(b)db - q\int_{c-v}^{\bar{b}}cf(b)db + \int_{\frac{c-vq}{q}}^{\bar{b}}cf(b)db$$

$$= q\int_{c-v}^{\frac{c-vq}{q}}(b+v)f(b)db - q\int_{c-v}^{\frac{c-vq}{q}}cf(b)db + (1-q)\int_{\frac{c-vq}{q}}^{\bar{b}}cf(b)db$$

$$= q\int_{c-v}^{\frac{c-vq}{q}}(b+v-c)f(b)db + (1-q)\int_{\frac{c-vq}{q}}^{\bar{b}}cf(b)db > 0$$

This would be gain from demonstration.

Proof of Proposition 3:

We know that $q = \frac{p}{F^{-1}(1)} \equiv \beta$ is a minimum level of fit required for the market demand to be positive. For the range of $\beta \leq q \leq 1$, the gain via additional demand is $q\int_{p}^{\frac{p}{q}}(b-c)f(b)db$ and the gain from preventing waste is $(1-q)\int_{\frac{p}{q}}^{\bar{b}}cf(b)\,db$; and for $0 \leq q < \beta$, the gain from preventing waste is zero since there was no demand before demonstration, and the upper bound of the private benefit is $\bar{b}$. Therefore, the demonstration gain function for $0 \leq q < \beta$ becomes $q\int_{p}^{\bar{b}}(b-c)f(b)db$. Since demonstration gain function is defined as the sum of gain from additional demand and gain from preventing waste, the expression for the demonstration gain function follows.

i) Let $G1(q)$ be $G(q)$ for $\beta \leq q \leq 1$ and $G2(q)$ be $G(q)$ for $0 \leq q < \beta$ in equation (21). $G1(q)$ is the sum of two continuous and twice differentiable functions, so it is also continuous and twice differentiable.

$$\frac{\partial G1(q)}{\partial q} = \int_{p}^{\frac{p}{q}} (b-c) f(b) db + q\left(\frac{p}{q} - c\right) f\left(\frac{p}{q}\right)(-\frac{p}{q^2})$$
$$- \int_{\frac{p}{q}}^{\bar{b}} cf(b)db + (1-q)\left(\frac{p}{q^2}\right) cf\left(\frac{p}{q}\right)$$

$$= \int_{p}^{\frac{p}{q}} (b-c) f(b) db - \int_{\frac{p}{q}}^{\bar{b}} cf(b)db - q\left(\frac{p}{q} - c\right) f\left(\frac{p}{q}\right)(\frac{p}{q^2}) + (1-q)\left(\frac{p}{q^2}\right) cf\left(\frac{p}{q}\right)$$
$$= \int_{p}^{\frac{p}{q}} bf(b)db - \int_{p}^{\bar{b}} cf(b)db - \left(\frac{p}{q^2}\right) f\left(\frac{p}{q}\right)(p-c)$$

$$\frac{\partial G1^2(q)}{\partial q^2} = -\left(\frac{p^2}{q^3}\right) f\left(\frac{p}{q}\right) - (c-p)\left(\frac{p}{q^3}\right) f\left(\frac{p}{q}\right)(2 + \frac{p}{q}) < 0$$

This is because the first term is always negative, and the second term is non-positive for $p \leq c$. In our setting, price is either equal to (in the absence of subsidies) or less than unit cost (in the presence of subsidies). Thus $G1(q)$ is strictly concave function on $\beta \leq \mathrm{q} \leq 1$. For $0 \leq q < \beta$, $G2(q)$ is also continuous and differentiable.

$$\frac{\partial \mathrm{G2}}{\partial \mathrm{q}} = \int_{p}^{\bar{b}} (b-c) f(b) db > 0 .$$

Therefore, $G2(q)$ is increasing on $0 \leq q < \beta$.

ii) Follows from Proposition 1 (ii) and the definition of the Demonstration Gain Function. If we plug $q = 0$ and 1 into $G(q)$, we know $\lim_{q \to 0} G(q) = G(0) = G(1) = \lim_{q \to 1} G(q) = 0$.

iii) $G1(q)$ is bounded and strictly concave, thus, it has an interior unique maximum. Let $\tilde{q} \equiv$ $argmax\ G1(q)$. We now show that $G1(q)$ and $G2(q)$ are continuous at β.

$\lim_{\mathrm{q} \to \beta} \mathrm{G1(q)} = \beta \int_{p}^{\bar{b}} (b-c) f(b) db = \lim_{\mathrm{q} \to \beta} \mathrm{G2(q)}$, thus $G1(q)$ and $G2(q)$ are continuous at β. Since $G2(q)$ is positive and increasing in q, $G2(q)$ has a maximum value at the bound of β. Thus $G(q)$ has a unique maximum at $\tilde{q}$, where $\beta \leq \tilde{q} \leq 1$. Define $Gmax \equiv G(\tilde{q})$.

Proof of proposition 4

The steps of the proof are clear from Figure 6.

i) Define net gains from demonstration as $H(q) \equiv G(q) - E$.

For $E = 0, H(q) > \; for\ all$ $0 < q < 1$.

For $E > Gmax \equiv G(\tilde{q}),\; H(q) < 0\;\; for\ all\ q$. That is for sufficiently high cost of demonstration, net gains from demonstration are negative.

From Proposition 3, we know that $G(q)$ is unimodal, and intersects X-axis at 0 and 1. Since E is constant, $H(q)$ is also unimodal. For $0 < E < Gmax, H(q)$ intersects X-axis at q_L and q_U, where q_L and q_U are in the interiors of 0,1. Demonstration results in positive net gains for $q_L \leq q \leq q_U$.

ii) From i), we know that $\mathrm{G}(q_l) =$ E for $0 \leq q_l < \tilde{q}$. Since $\mathrm{G}(q)$ is a non-decreasing function in $0 \leq q_l < \tilde{q},\; q_l{}' \equiv G^{-1}(E') \geq G^{-1}(\mathrm{E}) \equiv\; q_l$ if $E' \geq E$. Similarly, for $\tilde{q} \leq q \leq 1$, G(q) is non-increasing, so $q_u{}' \equiv G^{-1}(E') \leq G^{-1}(\mathrm{E}) \equiv\; q_u$ if $E' \geq E$.