Adopting New Technologies – Is Shirking Inevitable?*

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Abstract

We look at a very simple principal agent model where workers need to collaborate in order to adopt a new technology. In these models shirking becomes inevitable. We argue that while some people may shirk not everyone will. We look at the dynamics of this process in an evolutionary framework and argue that even without any mechanism design some people will not shirk even when the individual incentive to shirk exists. Further, we argue that more people will collaborate as the the size of the workforce increases. These results have important managerial implications.

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1 Introduction

In this paper we run a theoretical horse race between two behaviors – shirking and collaborating. We couch this in the context of a population of workers who have to adopt a new technology in the form of a new information system. Collaborating workers would adopt the new system while the shirkers would resist the adoption and free ride. We stack the deck in favor of shirking. This gives us a game that resembles the Hawk Dove game. Such games allow us to model the dynamics of technology adoption where adoption of a new technology is costly in that it requires effort, but has a clear benefit because it creates value that is non excludable but not non rival. We argue that in these sorts of scenarios, resistance to new systems is not an inevitable outcome even if the decks are stacked in favor of resistance. We are not adding to the theory of evolutionary games here – merely applying a well known result to the interesting and little investigated problem of resistance to adopting new information systems at the individual level.

Researchers have typically viewed resistance to the adoption of a new information system as a black box while acknowledging that it is a critical variable in deciding whether the new technology will be adopted or not (Lapointe and Rivard, 2005). Of the few papers that explicitly model technology resistance (Joshi, 1991; Marakas and Hornik, 1996; Markus, 1983; Martinko et al. 1996; and Lapointe and Rivard, 2005) none focus on the evolution of this resistance. They focus instead on either the outcomes of resistance to adoption at the organizational level, or on processes that lead to adoption that are unrelated to individuals' incentives.

Markus (1983) assumes that resistance to new technology may not necessarily have a negative effect on the organization. Such resistance could be dysfunctional if it has negative effects on productivity but could have a positive impact if the new technology increases stress and reduces productivity. Joshi (1991) argues that technology systems that generate inequitable distribution of the benefits of the technology will be resisted. Marakas and Hornik (1996) view resistance as a form of communication about technology that is inherently flawed and therefore detrimental to the organization. Martinko et al. (1996) focus on techniques to alleviate resistance when it could lead to situations where the organization does not meet its objectives. Note that none of these investigations study the effects of the resistance on the individual or the process that may lead to resistance.

Those investigations that do study the process of technology adoption (or resistance) within the organization tend to focus on the relationship between resistance and certain antecedents: the organizational distribution of power (Markus, 1983), fairness of exchange (Joshi, 1991), and uncertainty about the impact of something new (Marakas and Hornik, 1996). Again, this is studied at the level of the company or the organization Lapointe and Rivard (2005) do look at the process at different levels within the organization, but still not at the individual level

We seek to add to this literature by directly looking at how incentives at the individual level affect the process of adoption or resistance to new information systems. We use a simple, and well known evolutionary game theory model to explore whether resistance to technology is inevitable at the level of the individual adopter. To this end, we develop a model that delineates two culturally determined behaviors: one where the individual collaborates to adopt a new technology and another where the individual resists by shirking and not adopting the technology. We find that there is no clear winner. Indeed whether one behavior prevails over another depends on the proportion of people who are collaborators relative to shirkers. Our results also suggest that shirking is not a universal phenomenon even if it is the most "rational" thing to do. Further, our results suggest that a new technology will penetrate a work environment if there is a benefit to it, even without a formal managerial policy enforcing its adoption.

This paper therefore joins a stream of literature that looks very specifically at why there may be resistance to a new system. Our contribution is in modeling the process that leads to resistance by explicitly including the decision making behavior at the individual or employee level. The rest of the paper is as follows: In section 2, we develop our model by placing a standard model of shirking in the context of an evolutionary model. In section 3 presents and discusses the three propositions that follow from our model. Section 4 concludes.

2 The Basic Model

In this section, we first present a standard model of shirking. This model relies heavily on Shy (1995). We then use the results from this model to analyze the process of adoption or resistance by studying it in the context of an evolutionary game theoretic model

2.1 The Shirking Model

Consider a company that is adopting a new information system that the CEO knows will add value V to the company. Suppose there are N workers in this firm who are to adopt this new technology. Each worker puts in an effort e_i in order to adopt the system. The value created by adopting this technology jointly is

$$V = \sum_{i=1}^{N} \sqrt[2]{e_i}. \tag{1}$$

Each i^{th}worker receives compensation w_i. We assume that the value created from adopting this new technology is distributed evenly among the workers such that

$$V = \sum_{i=1}^{N} w_i. \tag{2}$$

All workers have identical preferences, given by the following utility function:

$$U_i = w_i - e_i \tag{3}$$

In this paper, we ignore the manager or principal's optimization problem since we really want to see whether workers shirk or not. In other words, at this stage, we focus solely on how agents behave within the group and abstract away from the principal's problem.

If all workers are able to observe each other's efforts, then there are no monitoring issues. In this case, workers collaborate to maximize their utility levels. Thus, the representative effort level e^* solves

$$\underset{e_i}{Max} U_i = w_i - e_i \tag{4}$$

such that each worker receives the same wage w and puts in the same effort e. So:

$$\underset{e_i}{Max} U_i = \underset{e_i}{Max}(w - e) = \underset{e_i}{Max}(\frac{V}{N} - e) = \underset{e_i}{Max}(\frac{N\sqrt[2]{e}}{N} - e). \tag{5}$$

Solving for the maxima therefore gives us $e^* = 1/4$. Given this effort level, the total value created from adopting the new technology is obtained from equation (1). Thus $V^* = N/2$. Since we assume that V^* is distributed equally among the workers, each worker gets paid $w_i = 1/2$. Therefore each workers utility, from equation (3), is $U^* = 1/4$. This utility is the outcome of collaborative behavior when everyone collaborates, that is when individuals belong to a culture of collaboration where monitoring is unnecessary.

Now lets say that workers cannot monitor each other and neither can their manager. We continue to assume that each worker is compensated equally for adopting the new technology by being paid $w_i = V/N$. Each worker has now an incentive to maximize his or her utility and take advantage of the new system by free riding. Of course, in this standard formulation, each worker maximizes his or her own utility and assumes that all the other workers are putting in more effort. Thus each worker solves the following optimization problem:

$$\underset{e_i}{Max}(w_i - e_i) \tag{6}$$

Since, $w_i = V/N$ we can substitute for V from equation (1) into equation (6) to give us

$$\underset{e_i}{Max}(\frac{\sqrt[2]{e_i} + \sum_{j=1}^{N-1} \sqrt[2]{e_j}}{N} - e_i) \tag{7}$$

where the j^{th} worker shirks when the other $N-1$ workers do not. Thus the optimum effort put forth by each worker when he is not being monitored solves equation (6) to give us $e_S^* = 1/4N^2$. Note that if there was only one worker, she would put forth the optimum effort $e^* = 1/4$. Thus $e^* > e_S^*$ for any $N > 1$. Further, as the number of workers increases, each worker will put in less and less effort. In other words, the incentive to shirk rises as the number of workers increase.

Now, if one worker shirks, then the total value created is $V_S^* = \sum_{j=1}^{N-1} \sqrt[2]{e_j^*} + \sqrt[2]{e_S^*} = 1/2N + (N-1)/2$. Thus, given our assumption about wages, each worker is paid $w_S^* = 1/2N^2 + (N-1)/2N$. Given this, the shirking worker's utility is:

$$U_S^* = 1/2N^2 + (N-1)/2N - 1/4N^2 = (2N^2 - 2N + 1)/4N^2$$

and the utility of each of the other collaborators is:

$$U_C^* = 1/2N^2 + (N-1)/2N - 1/4 = (N^2 - 2N + 2)/4N^2.$$

U_S^* is then the return to the worker who decides to shirk in an environment where collaboration is the predominant culture and U_C^* is the return to the worker who collaborates in the presence of one shirker.

If everyone shirks, then the total value created from adopting the new technology is $V_{ES}^* = \sum_{i=1}^{N} \sqrt[2]{e_{iS}^*} = N \sqrt[2]{(1/4N^2)} = 1/2$. Thus each worker is paid a wage of $1/2N$. The utility for each shirker is:

$$U_{ES}^* = 1/2N - 1/4N^2 = (2N-1)/4N^2.$$

Once again, this utility is the outcome of a very specific non strategic behavior predicated in a culture of shirking.

2.2 The Evolution of Shirking

Next, we place the simple model of shirking developed above in the context of an evolutionary model. The payoffs developed above are fairly well known in the literature. We reinterpret these payoffs as the outcomes for individual employees who are operating in a culture of shirking or a culture of collaboration. We set out to answer two questions: First, can a worker who decides to resist new technology survive in a cultural environment of collaboration or would the collaborative culture be resistant to such a mutation in behavior? In other words, we explore whether a culture of collaboration is resistant to invasion by mutants who shirk. Second, since we have two behaviors in a population of workers, shirking and collaborating, if there is no formal mechanism to ensure collaboration, is it inevitable that the shirking behavior becomes the fitter behavior? Indeed this is the assumption behind the need to design a mechanism that would make collaboration incentive compatible. We find that collaboration as a culture is resistant to shirking or resistant to mutations among the population, and that even without any enforcement mechanism, shirking is not an evolutionary stable outcome for the population as a whole.

In our model, workers are boundedly rational in the sense that some start off being shirkers while others are collaborators. Each type behaves according to the utility maximization procedures described in the section 2.1 above. Note that these procedures do not lead to Nash equilibria. They merely represent the utility outcomes when people behave in a certain way. For example, the utility to the shirker in the case of one person shirking and everyone else collaborating is given by equation (7) in a deterministic way. We ignore the possibility of *strategic* interaction between shirkers and collaborators in this process since our intent is to focus on the viability of shirking behavior in a boundedly rational (and therefore non strategic) population of collaborative employees. Of course both cultures do interact with each other in a way that determines the outcomes of their behavior. They just cannot switch behaviors or strategies as a result of these interactions.

In our model, a new technology is being introduced in a population of workers where a proportion p will adopt the technology while a proportion $1-p$ will resist the new technology by free riding (shirking) off the collaborators. For simplicity, we assume that workers are paired within the group. This pairing is random. Thus each worker (whatever their underlying behavior) has a p chance of being paired with a collaborator and a $1-p$ chance of meeting a shirker. In this pairing, the payoffs represent the fitness of a particular behavior. The shirker operates in a culture of collaborators. So the fitness to the shirker depends on the assumption that everyone else is collaborating, while the fitness to the collaborators is derived from the total value created when at least one of their culture shirks. In other words the fitness of each behavior is determined by the simple model introduced in the previous sub-section This is represented in Table 1 below[1].

Notice that shirkers gain the most if everyone else in the population collaborates since the total value created by adopting this new technology is a monotonic function of effort. Thus, this assumption has the added advantage of making the strongest possible case for shirking. Effectively then we are testing which of these two extreme behaviors is likely to prevail.

The evolutionary game represented in Table 1 has the characteristics of a Hawk Dove game. We argue that such evolutionary games can represent reality in technology adoption settings since new technology acts as a resource that creates value. Shirkers would like to appropriate this value without the cost of

[1] Table 1 does not represent a normal form game in the usual sense. Thus there is no interaction in the strategic sense between the shirkers and the collaborators. The matrix merely notes the outcomes of pre established behaviors as is usual in evolutionary game theory models (Gintis, 2000, pp. 149)

	Collaborate(p)	**Shirk(1-p)**
Collaborate	$1/4, 1/4$	$\frac{(N^2-2N+2)}{4N^2}, \frac{(2N^2-2N+1)}{4N^2}$
Shirk	$\frac{(2N^2-2N+1)}{4N^2}, \frac{(N^2-2N+2)}{4N^2}$	$\frac{(2N-1)}{4N^2}, \frac{(2N-1)}{4N^2}$

Table 1: Fitness

the effort in adopting the technology. Collaborators, of course, both put in the effort and split the gains from this effort.

We acknowledge that there may be any number of other behaviors that workers may have, including ones that explicitly recognize that some people will shirk and others will not. Indeed one might expect these behaviors to be endogenous. However, as mentioned above, we stick with our extreme and naive formulation of what it means to shirk and what it means to collaborate since we are testing whether collaboration can prevail even when shirking is favored in our stylized model.

3 Evolutionary Dynamics

In this section we find the evolutionary stable equilibrium (ESS) and develop and present three propositions that arise from our solution.

3.1 Is Shirking Evolutionarily Stable?

We assume a simple replicator dynamic process generates selective forces in this model. We use this approach merely to reveal an ESS. It is well known that in evolutionary 2x2 games, attractors are ESS (e.g. Harrington, 2009, pp. 514). Therefore this replicator dynamic approach will reveal ESS by revealing locally stable rest points or attractors. Our focus in this paper is to test whether collaboration can be a successful strategy or not, i.e. can collaboration be part of an ESS. Thus, the replicator dynamic process is merely used as a technique to identify an ESS. We are making no claims about whether the replicator dynamic is actually the process through which people learn to be one type or another. So, in what follows, one should focus on the results of this replicator dynamic, rather than on the process itself.

The replicator dynamic process simply states that whenever a particular behavior's fitness exceeds the average fitness of the population, that behavior will increase in the population. Since the average fitness remains unchanged in these models, we can simply compare the expected fitness from one behavior with to the other. If the expected fitness of one behavior exceeds that of the other, then the first behavior will increase in the population.

Here, the expected fitness from collaborating is

$$4p + (1-p)\frac{N^2 - 2N + 2}{4N^2} \tag{8}$$

while the expected fitness from shirking is

$$\frac{2N^2 - 2N + 1}{4N^2}p + (1-p)\frac{2N-1}{4N^2}. \tag{9}$$

Thus collaboration is the fitter strategy only when

$$4p + (1-p)\frac{N^2-2N+2}{4N^2} > \frac{2N^2-2N+1}{4N^2}p + (1-p)\frac{2N-1}{4N^2}. \qquad (10)$$

Solving for p above tells us that collaboration is fitter only when $p < \frac{N-3}{2(N-2)}$.

Note that $\frac{N-3}{2(N-2)} < 1$ for any $N \in \mathbb{R}^+$, and $\frac{N-3}{2(N-2)} > 0$ for any $N > 3$. Thus, for any group larger than three members, there always exists a positive fraction of the population of workers for whom collaboration is a fitter strategy. Thus for any actual proportion of the population less than $p = \frac{N-3}{2(N-2)}$, the proportion of collaborators will increase in the population. However, for any proportion of collaborators above $p = \frac{N-3}{2(N-2)}$, shirking is a fitter strategy and the proportion of collaborators in the population will decrease to $p = \frac{N-3}{2(N-2)}$. Thus, $p^* = \frac{N-3}{2(N-2)}$, is an attractor point and therefore an ESS.

This leads to Proposition 1:

Proposition 1 *The ESS is at* $p^* = \frac{N-3}{2(N-2)}$.

This proposition states that there will always be some collaborators in the population. In other words, even when everyone has an incentive to shirk, some people will always collaborate and adopt a new technology. Further, this depends only on N, the number of workers in the workplace.

The next obvious question then is what happens to the proportion of collaborators, p, as the number of workers increase. In other words, does the size of the group matter. This leads to Proposition 2:

Proposition 2 p^* *is increasing in* N *since* $\frac{d}{dN}(\frac{N-3}{2(N-2)}) = \frac{1}{2(N-2)^2} > 0$.

The proof of this proposition is obtained from the first derivative of p^*. This proposition implies that as the population of workers increases, so will the proportion of the population that chooses to collaborate.

This may seem counterintuitive. One might expect shirking to become more prevalent as the number of workers increases. However, note that the expected fitness from collaborating rises with N^2 only if $p > 1/2$, and falls otherwise.[3] This dynamic leads to proposition 3:

Proposition 3 *The proportion of collaborators never exceeds 50% as* N *rises.*

We find that as N rises, at the limit, the expected payoff from collaborating is

$$\lim_{N\to\infty}(p/4 + (1-p)\frac{N^2-2N+2}{4N^2}) = \frac{1}{4}. \qquad (11)$$

Further as N rises, at the limit, the expected payoff from shirking is

[2] Since $\frac{d}{dN}(4p + (1-p)\frac{N^2-2N+2}{4N^2}) = -\frac{1}{2N^3}(N-2)(p-1) > 0$ since $p < 1$.

[3] $\frac{d}{dN}(\frac{2N^2-2N+1}{4N^2}p + (1-p)\frac{2N-1}{4N^2}) = \frac{1}{2N^3}(2p-1)(N-1)$. Now for any $N > 1$ $\frac{1}{2N^3}(2p-1)(N-1) > 0$ only if $p > 1/2$ and less than 0 otherwise.

$$\lim_{N \to \infty} \left(\frac{2N^2 - 2N + 1}{4N^2} p + (1-p) \frac{2N-1}{4N^2} \right) = \frac{1}{2} p. \tag{12}$$

Once again the ESS is obtained where the expected fitnesses are equal i.e. where $1/4 = p/2$. In other words as $N \to \infty$, $p^* \to 1/2$. This proves proposition 3.

In this section, we randomly pair collaborators and shirkers in an evolutionary game where the population is adopting a new technology. We use a standard principal agent model to generate payoffs that we use as the fitness for workers (employees) who are operating in this culture of shirking or collaboration. We argue that such behaviors exist in settings where introducing a new information system leads to resistance amongst employees. Our model yields the following results:

First, we find that there will always be collaborators in the team. One could argue that all employees should resist so long as they believe that others will adopt the new technology. Indeed, traditionally, this is the starting point for designing mechanisms that aim at reducing the incentive to shirk in strategic settings and enforcing efficient outcomes. We find that even without such mechanisms, resistance to new technology is not inevitable. Some members of the team will always chose to collaborate. Recall that we set up our model by stacking the deck in favor of shirking behavior. This result therefore implies that even when everyone has an incentive to shirk, some people will always collaborate to adopt a new technology. This result has policy implications. For example, it suggests that new sorts of information technology that provide value to a workplace and therefore increase worker productivity and wages will always penetrate the workplace. This has implications for both worker productivity and IT security as technologies become more user centric. Further, we find that this penetration depends only on the number of workers in the workplace.

The question that arises naturally out of this finding is whether the culture of shirking will predominate over a culture of collaboration. In other words, is this result stable. We find that it is. We find that even when people make mistakes – mutate – the system is stable.

Finally, we explore what might happen in this situation if the size of the group increases. In other words, are more or fewer workers likely to be collaborators as the number of workers increases. Indeed, one might expect that as the size of the group increases, there should be more shirking. We find this not to be the case. In fact, we find that as the size of the team increases, the proportion that chooses to collaborate increases as well. However, we do find a "glass ceiling". We find that as the size of the team increases, the proportion of collaborators will increase, but never exceed fifty percent of the population.

4 Conclusion

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