Agency Problems and Airport Security: Quantitative and Qualitative Evidence on the Impact of Security Training

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We analyze the issue of agency costs in aviation security by combining results from a quantitative economic model with a qualitative study based on semi-structured interviews. Our model extends previous Principal-Agent models by combining the traditional fixed and varying monetary responses to physical and cognitive effort with non-monetary welfare and potentially transferable value of employees' own human capital. To provide empirical evidence for the trade-offs identified in the quantitative model we have undertaken an extensive interview process with regulators, airport managers, security personnel and those tasked with training security personnel from an airport operating in a relatively high risk state, Turkey. Our results indicate that the effectiveness of additional training depends on the mix of 'transferable skills', and 'emotional' buy-in of the security agents. Principals need to identify on which side of a critical tipping point their agents are to ensure that additional training, with attached expectations of the burden of work, aligns the incentives of employees with the principals' own objectives.

KEY WORDS: Semi-structured interviews; principal–agent models; public policy; mixing qualitative and quantitative analysis; security risk; human capital.

1. INTRODUCTION

Security officers are an essential component of the mechanisms that secure airports across the world. Since the first inter-ministerial conference after 9/11, the importance of their training has been stressed in the revision of the International Civil Aviation Organization's Annex 17 (the "Aviation Security Manual" that regulates airport security around the world). Training security personnel is

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however expensive: according to a study for the EU Commission,[?] it accounts for around 2% of indirect expenses for airport security. A critical issue for a policy maker or security manager is to find an appropriate training portfolio that results in a suitable level of security. Unfortunately, data on human errors in airport safety and security incidents is often limited or does not capture some of the factors shaping officers' performance,[?] and prior works in risk analysis[? ?] have highlighted how empirical approaches based on the statistical analysis of historical security incidents may not work in this scenario.

Our methodological contribution is to combine a quantitative principal-agent (P–A) framework for modeling the effective effort of security personnel with a qualitative case study to validate the outcomes suggested by the model. This might be an

alternative approach for the risk analyst precisely when empirical evidence is limited and controlled studies are ethically impossible. To illustrate our approach, we have chosen an airport in the Eskişehir region of central Turkey, a zone with a relatively high level of risk. The airport is run by the organization entrusted by the Turkish Civil Authority for nation-wide security training of airport security staff. Hence, we have been given an almost unprecedented degree of access to airport security stakeholders to conduct extensive interviews *in situ.*

A P–A framework is particularly well suited for analyzing security in civil aviation because the stated goal of security authorities entrusted with this task is managing risk; however, the implementation of policies at an operational level is performed by staff who are usually paid at or below the national average for their respective countries. For example, the US government's Federal employee pay guide at the 'Office of Personnel Management", `http://www.opm.gov`, shows that the salary steps for the Transport Security Administration (TSA) main bands lie between 1 and 5, with a maximum 10th class salary of just over $39,000 in 2014. The national median pay in the US in 2013 was $51,300. Interview evidence from our Turkish stakeholders (see §**??**) indicates that the comparative level of wages, relative to average national incomes, is not materially different from that of the US and anecdotal evidence suggests that may even be worse.

In this scenario, a misalignment between the goals of the principal (the government authority) and the goals of the agents (the security officers on the ground) is a concrete risk to be faced.[4] Training has been traditionally viewed as an appropriate mechanism to increase the agent's "intrinsic motivation" to achieve the principal's goals when financial incentives are absent or misaligned as illustrated by Bénabou and Tirole,[? ?] Casadesus-Masanell[?] and Murdock.[?] Our quantitative model includes the typical mechanism with fixed and incentive wage rates and explicitly models the notion of intrinsic motivation in the spirit of Bénabou and Tirole[?]

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[4]Suitable performance-based contracts may be designed to address this issue. However, the presence of multiple objectives may make these contracts suboptimal on the ground. For example, Menneer et al.[?] have shown that detecting multiple targets (a common requirement in a security screening procedure) may undermine the overall accuracy and performance of screeners and cause unintended consequences. This indicates the difficulty in designing a good performance-based contract.

where agents exhibit an emotional engagement with the objectives of the principal. We add a third component that captures an alternative quasi-monetary reward: the ability to obtain certifiable skills improving future employability. This notion is similar to the classic concept of 'forward looking human capital' in Becker[?] and Schultz.[?]

To validate the model, we combine this quantitative approach with a qualitative case-study based on the classic methodological principles set out in Yin[?] and conducted with the approach of Bloom and Van Reenen[?] by using focused semi-structured interviews with purposive sampling of stakeholders. The interviews validate that the behavior predicted by the model, when training arrangements vary (e.g. signs of derivatives or tipping points), is indeed what is experienced by stakeholders with relevant experience on the field.

Our approach does not allow to make point predictions; however, it does allow the risk analyst to disentangle the myriad of explanations suggested by subject-matter experts on the relative effectiveness of security training in the field. An appropriate training portfolio can then be designed.

The remainder of this paper is organized as follows: §**??** provides details on the geo-political and institutional arrangements for airport security provision in Turkey and some background on our specific airport and its unique importance to Turkish aviation security. §**??** reviews the relevant literature. In §**??** we present a series of simple P–A models that are specifically attuned to the aviation security setting and outline the important trade-offs that factor into the creation of explicit and implicit incentive compatible contracts. §**??** carefully outlines the objectives, methodology and setting for our semi-structured interviews and §**??** then proceeds to integrate the results from these interviews with the results of the theoretical model to illustrate the agency problems and the nature of the trade-offs facing the policy maker. Finally, in §**??** we provide some commentary on the complementarity of this type of approach and frequentist empirical analysis and some final general concluding remarks and opportunities for future research.

2. AIRPORT SECURITY IN TURKEY

Turkish citizens and visitors have been the victims of several terrorist related activities and the need to protect citizens and visitors using airports is a pressing need for public policy-makers in Turkey.

Table I . Selected Terrorist or Similar Incidents in Turkish Airports from 2001 to 2013.

Year	Type of Incidents	Description
2001	Hijack attempt	Unukova Airlines Istanbul-Moskow flight. It was hijacked by three Chechen terrorists. Flight diverted to Medine, UAE. Three people died in the police operation including one terrorist.
2003	Hijack attempt	Turkish Airlines Malatya-Ankara-Istanbul flight. Hijacker took two cabin crew hostages and released a manifesto and wanted to go Moscow. No injury or dead.
2004	Bomb attack	Turkish Airlines Izmir-Istanbul flight. After the flight landed and passengers had embarked, an object was found by cleaning staff exploded. Three people were injured.
2006	Arson	Fire at the cargo area in Istanbul Ataturk airport. Three people were injured and millions of dollars in damage were caused. The Kurdistan Freedom Hawks claimed responsibility.
2007	Hijack attempt	Pegasus Airlines Diyarbakir-Istanbul flight hijacked by a hijacker with a bomb threat. Pilot landed the airplane to the Ankara Esenboga airport.
2009	Hijack attempt	Egyptair Istanbul-Cairo flight. The would-be hijacker used a false passport.
2012	Bomb attack	Explosive device placed at Diyarbakir airport. It defused before explosion.
2013	Cyber attack	Custom systems of Istanbul Ataturk and Sabiha Gokcen airports were blocked for a while and flights delayed.

Note: Source: ITERATE database and own investigation. The examples listed in the table do not distinguish whether the attempts were successful. They were used to show how security incidents might cause mass casualty and property damage.

Table **??** displays selected examples of terrorist or similar incidents in Turkish airports from 2001 to 2013. Whilst none has caused mass casualty, several came close to near mass casualty events.

At the time of writing (2014), Turkey has been in membership negotiations with the European Union (EU). As part of the accession, the variation in policy approaches to security between Turkey and the EU has required particular attention in regard to conforming with the Acquis Communitaire and other elements of EU constitutional law. In §**??** this topic is intertwined with the operation policy considerations and some commentary is provided.

The Directorate General of Civil Aviation (DGCA) is the Turkish government agency responsible for aviation security. It has a dedicated unit responsible for training, education, research and inspection specifically relating to airport terminal, airside and ground security. In the sequel, we refer to aviation security as the set of all security issues relating to air transport and 'airport security' as the subset of aviation security relating specifically to terminal, airside and ground security of passengers and planes.

The DGCA is staffed by personnel from various national government agencies and the state police. The DGCA is one of the main providers of security training programs for airport security staff via one of the Turkish Universities (Anadolu University), who are not normally government employees, in contrast to, for instance, the US Transportation Security Administration (TSA) who are federal employees. A key focus of our analysis will be the impact of training as this forms a very significant component of the overall security budget. In terms of contractual liability for security incidents, the arrangements are complex, only partially documented and often legally untested. This is discussed, albeit anecdotally, in some detail in §**??**.

The International Civil Aviation Organization (ICAO), an agency of the United Nations, codifies the general principles and techniques used in aviation and provides much of the security requirements for civil air transport (Annex 17). The International Air Transport Association (IATA), a trade organization, implements and delivers the training courses needed to meet those requirements on behalf of ICAO. As the national civil aviation body, the DGCA is responsible for the local implementation assuring that Turkish airports are compliant with the various international requirements set down by IATA and ICAO, and that needs of the local security conditions are appropriately covered.

Therefore, there is a strong correspondence between DGCA training courses and IATA and ICAO training requirements (and their own training courses). For instance, "Module 16: Hazardous Substances" of the DGCA training requirements is primarily driven by IATA and ICAO requirements in this area. As another example, the IATA course entitled "Unruly Passenger Prevention and Response" and DGCA "Module 8: Dealing with Potentially Disruptive Passengers" cover essentially identical topics. The DGCA requirements add several local details specific to Turkey, such as additional details

on the determination of offensive acts specific to the Turkish legal system.

The types of training undertaken by security agents can be broadly classified into two areas, we denote these '*general security training*' and '*technical/specific security training*'. In Table **??** we provide a short summary of IATA and DGCA training modules to illustrate the observed differences in general security training versus technical/specific security training. General security training covers general awareness of security issues and a broad overview of security techniques. A large component of the training aims at ensuring that the agents have a clear understanding of threats, objectives, and tools of the DGCA. Technical/specific security training focuses on role specific aspects such as proper operation of x-ray machines, firearms training and identification of suspects from behavioral patterns. A key difference between general security training and technical/specific security training is the element of *in situ* effort required to successfully complete the courses. In general, either directly or indirectly, technical/specific security training requires the agents to engage in additional effort within their working domain to ensure that the requirements of the course are successfully met, and is usually concluded by a certificate of performance. In contrast, general security training is primarily a classroom or on-line exercise, and is typically concluded by a certificate of attendance.

Our interviews were conducted at Anadolu airport in Eskişehir and it is useful to provide some context on why this airport is an appropriate case for the study. Anadolu airport is the DGCA main training centre for airport security staff in Turkey. It is also a training centre for Turkish air-traffic controllers and provides training and accreditation for staff across the airport domain in Turkey. Moreover, it is a functioning airport operating within the town of Eskişehir in the region of Central Anatolia. The airport itself is part of the university and provides a practical test-centre for vocational courses on all aspects of the operations of airports including security, whilst actually operating as an airport itself.

The airport serves mainly as a hub for the town for the university students resident there. It is worth noting that the need for a reasonable sized airport in Eskişehir is due to the large number of transient students that Anadolu University supports. The university has around 23,000 students locally resident and nearly two million undertaking distance

learning. The reason for this large number stems from Anadolu University's status as the primary national distance learning centre in Turkey.

Over the course of their education, students are sometimes required on site and, with such a large student population, the turnover of travelers makes the airport of the University the 42nd busiest airport in the second most populous state in Europe, with 50,000 passengers traveling through it in 2013.

Our case study interviews encompass stakeholders from DGCA, staff trainers from Anadolu University and private companies, and members of the security staff from Anadolu Airport.

3. RELATED WORK

Our work aims at linking incentive issues between the parties in charge of airport security with an economic model. Securing critical infrastructures such as electricity, transportation and telecommunications involve multifaceted interactions among various internal and external parties.

One of the main issues is that the actions taken by participating parties might not be easily observed and monitored by those eventually accountable for the performance of the infrastructure. This type of problems has been commonly analyzed using P–A explanations. According to Eisenhardt[?] P–A theory provides valuable tools for studying situations in which the information is asymmetrically distributed among actors, such as the principal and collection of agents, and the actor's goals are in conflict with those of others (i.e., misaligned incentives). The theory therefore allows us to answer a question on how the principal can design a contract and a system of incentives (punishments and rewards) that make the agent behave in the best interest of the principal.

If monitoring agents' actions is costly, then it is likely that the principal will have incomplete information on the choice of actions by the agent. As such, there may be a moral-hazard element to the agent's action, when incentives are not fully aligned. In some cases, the principal often makes a payment to the agent based on the outcome after an action has occurred, transferring liability to the agent, which in some cases may impose an unfair cost sharing. In contrast if the principal is forced to pay the agent 'up-front' then the opposite effect may occur.[?,?]

For example, in the context of information security, Anderson et al.[?] argue that even when there is more spending on information security, many security breaches cannot be avoided as long as

Table II . Examples of Civil Aviation Security Training Modules offered by IATA and DGCA. [?]

Category	IATA	DGCA	Target groups
General Security Training	Aviation security awareness course; Aviation security awareness course for the leadership & Management training program; IATA Cargo security awareness; Building a future air-traffic-management (ATM) system; Effective employee background vetting	Security awareness training; Airport security; Screening of staff, passengers & cabin baggage; Airline business security; Aircraft baggage & cargo security; Cargo & mail security; Crisis management	All staff, all security staff or staff in each service area
Technical/Specific Security Training	Identify Passenger Prevention & Response; Predictive passenger screening; Passenger data program; Airport security operations optimization; Aviation cyber security; Aviation security management; Customs security & facilitation; Security audits & Quality control; Security X-ray screening operations	Control of potentially dangerous passengers; Passenger interviews & travel documents; Communication & body language; Screening of air cargo; Hazardous substances; Security management & leadership; Flight baggage screening	Security staff in each specific area

Note: Source: IATA Training Catalogue[?] and DGCA Training Manual. Whilst General Security Training generally awards no certificate or only certificate of attendance, Technical/Specific Security Training has a stricter rule (e.g., minimum marks) and provides a certificate of performance to participants with a minimum or higher grade.

moral hazard and adverse selection from misaligned incentives exist. This phenomenon may occur when the agent (i.e. an individual or organization) responsible for the security of the system is not directly exposed to a proportion of the losses resulting from a security incident and when monitoring is costly and is consequently incomplete. Without proper liability sharing regimes, P–A problems will arise and jeopardize security of systems in part or in whole.

Our work also builds on the literature on supply chain and homeland security with multiple agents. Atallah et al.[?] utilize simulation based models to discuss the incentive misalignments when developing secure protocols collaboratively between supply chain partners. Their results indicate that Pareto beneficial collaborative action can only be conducted when the private information of the partners is not collectively disclosed. Bakshi and Kleindorfer[?] demonstrate how a first-best outcome in supply chain security with asymmetric information can be achieved, when supply chain partners make some security investment. They further illustrate that, even if the retailer cannot observe the supplier's action, 'buy out' contracts can lead to a first-best outcome. Subsequently, Bakshi and Gans[?] explore a game-theoretic model that takes into account incentive and security issues, and identify an optimal security contract encompassing the U.S. Bureau of Customs and Border Protection, the trading firms and terrorists. In particular, they discuss moral hazard issues in the context of port security, where an important finding is that a properly designed

customs-trade partnership program can provide an incentive for trading firms to join the partnership program, and makes it possible to transfer some of the government's security burden to trading firms.

Our work is also related to the literature on 'intrinsic motivation' in behavioural economics and psychology. For instance, Murdock[?] models the agent's incentive structure with intrinsic motivation (an intrinsic incentive that has no direct effect on the agent's directly measurable rewards) and argues that intrinsic incentives and implicit contracts are complements. Bénabou and Tirole[?] provide a formal model to discuss how explicit incentives may undermine the agents' motivation in the long run and how intrinsic motivation can improve the agents' performance. Casadesus-Masanell[?] presents a P–A framework taking into account only a fixed payment, and shows how intrinsic motivation can promote trust in the P–A relationship. Canton[?] also examines the power of intrinsic motivation particularly in public organizations, and identifies cases where material incentives lead to crowding-in or -out of intrinsic motivation.

4. THE MODEL

We initially present a standard model of agency, along Holmstrom and Tirole.[?] We then adjust the underlying assumptions of the model to include the effects of intrinsic incentives and transferability of human capital. The functional form that we utilize to adjust the standard utility function is partly

based on the work of Casadesus-Masanell[?] and Canton.[?] However, our treatment takes explicit account of human capital and training following the classic treatment of such issues in Schultz.[?]

While building on previous P–A literature with intrinsic motivation, our model is particularly attuned to the context of civil aviation security by capturing the following features: different agents, different policy measures to address agency problems, different types of security training, lack of robust data for statistical analysis, and rich anecdotal information.

4.1 The Benchmark Model

We focus on a P–A interaction where principal and agent are both on the security provision side. Games where attackers react to choices of the principal and the agent are possible. Recent research in this direction[? ? ?] have indicated that the only effect of this inclusion is to magnify the issues that we raise herein: the penalty for agency problems is even greater than when attacking effort is exogenous. For example, by modeling terrorists' critical attributes as a uncertainty parameter in a game-theoretic robust optimization problem, Nikoofal and Zhuang[?] formally proved the expected result that, as the defender becomes more uncertain about the attacker's valuation of targets, the overall defensive budget must increase and a greater portion of it should be allocated to more valuable targets.

The principal is a government agency representing the social planner (hereinafter, referred to as 'the government') and the agent is a worker conducting security on the principal's behalf. As for the agent, we therefore consider both police officers and security staff (e.g., security guards and X-Ray screeners) who work at an airport to meet the goals of the government (hereinafter, we refer both of them as 'the employee'). For the US case, the employment relation is direct as TSA is a federal agency that operates within airports. For European countries as well as Turkey there is a mix of approaches. In many cases the airport directly employs the security staff and as such is an intermediary agent. Similarly to the arguments regarding reactive attackers, adding layers of agents amplify the underlying P–A problems.[?]

To model the interaction between government and employee, we consider that the employee needs to comply with various security rules to avoid any penalty, but his action to comply with these rules is costly to him: he is adverse to taking action. The

Table III . Description of Model Parameters and Choices.

Principal's decision	
α	Incentive wage rate.
β	Fixed wage.
Agent's choices and parameters	
a	Employee's choice of effort.
r	Employee's level of risk aversion.
Welfare effect parameters	
ρ	Emotional satisfaction, feeling of responsibility.
δ	Employee's feeling of 'burden'.
γ	Marginal rate of transferability of effort to future income.
Environmental parameters	
σ^2	The variance of the shock ϵ and for convenience we set $k := r\sigma^2$.

mechanism itself and its parameters, are designed to be as simple as possible in order to focus on behavioral issues. For reference, model parameters and their intuition used throughout in the study are summarized in Table **??**.

Let a be the employee's action of compliance with security rules, x be the observable informative signal (i.e. outcome) from the action a, and ϵ be an exogenous shock. We have $x = a + \epsilon$. We can think of a as the level of care the employee takes for ensuring security and x as the airport security level achieved by his effort (measured by the magnitude of a). In our interviews the participants refer to effort in terms of perceived motivation. Mathematically, we compose effort and motivation as functions of each other to follow the extant literature on modeling behavior in economics.

Following Holmstrom and Milgrom,[?] the reward function is defined as $s(x) = \alpha x + \beta = \alpha(a + \epsilon) + \beta$ after informative signal $a + \epsilon$ has been realized. This implies that the employee has to bear some uncertainty associated with α.

The employee's cost of action is considered to be quadratic as suggested by Bénabou and Tirole,[?] $c(a) = a^2$, and hence is a strictly convex function with increasing marginal cost of action (i.e., $c'(a) > 0$ and $c''(a) > 0$). The employee's monetary rent from carrying out a can be denoted as $\alpha(a + \epsilon) + \beta - a^2$.

We assume that employees are prudent and risk averse since it is hard for them to bear any short-term financial losses with their limited resources (see §**??** for an empirical confirmation of this assumption). The corresponding constant absolute risk aversion (CARA) utility function is captured by the following

functional form

$$u_a = W - e^{-r(\alpha(a+\epsilon)+\beta-a^2)} \qquad (1)$$

where r is a coefficient of constant absolute risk aversion and W is the current wealth level which is a positive constant for our purposes. Hereinafter, the subscript in u_a is used to denote the agent.

The government would be naturally risk averse in terms of global management of civil aviation security. Yet, this would transfer into a multitude of risk mitigation measures (security personnel, body scans, X-rays, etc.), but not in a risk averse approach to individual measures such as employment contracts because the government can diversify its security portfolios. The principal's risk neutrality is a well accepted assumption in the context of employment contracts.[?]

The government's random net benefit can be defined as $u_p = x - s(x) = (1 - \alpha)x - \beta$ where subscript p denotes the principal. Next, we derive the certainty equivalents for both government and employee. The certainty equivalent of the government is

$$\pi_p = (1 - \alpha)a - \beta, \qquad (2)$$

To calculate the employee's certainty equivalent we need to make some assumptions on the distribution of the exogenous shock ϵ. For hyperbolic utility functions, of which the CARA function utilized herein is an example, negative shocks dominate the agent's effort choices.[5] Further, agents with this type prefer the lottery with a fixed loss L plus a random loss around 0 to a fixed loss of 0 plus a random loss around L; see Eeckhoudt and Schlesinger[?] for extended discussion on the implications of this effect, and also Kantor and Boros[?] for additional reasons to eliminate the large (and likely unknown) total loss from economic and effectiveness analysis of security measures. We can therefore eliminate the likely negative mean L of ϵ from consideration.

If the distribution of the stochastic outcomes ϵ is symmetric around zero, and moments greater than two are fully described by the second moment (variance) then the expected utility of a risk averse, prudent agent is weakly decreasing in variance of

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[5]For illustration, approximate ϵ with a one period binomial distribution $\epsilon = \{-\sigma, \sigma\}$, for respectively a negative and positive shock. We obtain the following values of the utility function $U(\sigma) = W(1 - W_0)$ and $U(-\sigma) = W(1 - W_0 e^{2r\alpha\sigma})$ where $W_0 = -e^{-r(\alpha(a+\sigma)+\beta-a^2)}$. Asymptotically, as $\sigma \to \infty$, we have $U(\sigma) = O(1)$ whereas $U(-\sigma) = -e^{O(\sigma)}$.

shocks. If we further restrict the distribution of shocks to being Gaussian, $\epsilon \sim \mathcal{N}(0, \sigma^2)$, then the stochastic component of the certainty equivalence of the payoff is fully described by the variance and is weakly decreasing in σ^2. The employee certainty equivalent payoff denoted π_a is therefore be as follows

$$\pi_a = \alpha a + \beta - a^2 - \tfrac{1}{2}r\sigma^2\alpha^2. \qquad (3)$$

The last term of π_a, the risk premium, is the product of $r\sigma^2$ and the incentive wage rate squared, α^2.

As a starting point, suppose employee's actions are fully observable without costs. In this symmetric information case, the first-best contract is attainable.

PROPOSITION 1: If the employee's action is fully observable, optimal contract and joint surplus are as follows:

$$\alpha^\dagger = 0, \quad a^\dagger = \tfrac{1}{2}, \quad \beta^\dagger = \tfrac{1}{4}, \quad \pi_p^\dagger + \pi_a^\dagger = \tfrac{1}{4} \qquad (4)$$

Proof. See Appendix: Proof of Proposition **??** $\square$

In practice, the employee's action is largely unobservable. Therefore, while the government wants to maintain more than a certain level of security, the employee may shirk his responsibilities if he can do this without being discovered and if the expected net gains from shirking are higher than those from exerting due care. We refer this model as a benchmark model, since it will be compared with the extended model presented in the following subsection. Hereinafter, superscript $\ddagger$ is used to denote the benchmark model.

The problem of identifying an optimal contract can be solved by maximizing the joint surplus $\pi_a^\ddagger + \pi_p^\ddagger$ subject to the incentive compatibility constraint: i.e.,

$$\max_\alpha \pi_a + \pi_p \quad \text{subject to} \quad a \in \arg\max \pi_a. \qquad (5)$$

The remaining parameter β is identified by the principal by setting the salary of the agent as non-negative. The optimal contract and joint surplus can then be expressed in terms of exogenous parameters.

PROPOSITION 2: The optimal contract, employee's effort and joint surplus, when the principal

is unable to observe the agents effort, are as follows:

$$\alpha^{\ddagger} = \frac{1}{1 + 2r\sigma^2}, \tag{6}$$

$$\beta^{\ddagger} = \tfrac{1}{2}r\sigma^2 \frac{1}{(1 + 2r\sigma^2)^2} - \tfrac{1}{4}\frac{\alpha^{\ddagger}}{(1 + 2r\sigma^2)}, \tag{7}$$

$$a^{\ddagger} = \tfrac{1}{2}\frac{1}{1 + 2r\sigma^2}, \tag{8}$$

$$\pi_p^{\ddagger} + \pi_a^{\ddagger} = a^{\ddagger}\frac{1}{1 + 2r\sigma^2}. \tag{9}$$

under the constraint that $r\sigma^2 \geq \tfrac{1}{2}$.

Proof. See Appendix: Proof of Proposition **??** □

From (**??**) and (**??**), $\alpha^{\ddagger}$ and $a^{\ddagger}$ are strictly decreasing in the employee's perceived risk, $r\sigma^2$. Hence, if the employee's perceived risk becomes sufficiently large, it may push him away from exerting due effort, and thus the contract may not achieve the objectives of the principal. The constraint on σ stems from the observation that a worker will not work for a negative salary ($\beta \geq 0$).

Comparing Proposition **??** with Proposition **??**, unobservable effort and subsequent moral hazard result in the decrease in the fixed payoff and the increase in the incentive rate from 0 to $1/(1 + 2r\sigma^2)$. They decrease the employee's action level and the government's overall net benefits.

4.2 Adding Motivations and Transferrable Skills

At this point we incorporate the impact of training and aspects of the agents behavior which go beyond the standard P–A modeling approach. We adjust the standard framework to incorporate how motivations and transferrable skills affect the employee's utility, and study how the optimal contract $\langle \alpha^{\ddagger}, \beta^{\ddagger}, a^{\ddagger} \rangle$ identified in the benchmark model changes.

Indeed, there is a growing literature that indicates that an employee's payoff might be a function of intrinsic preferences such as job satisfaction and peer recognition in addition to the direct monetary rewards captured by the simplest utility frameworks.[?][?][?][?] For example, Huselid et al.[?] demonstrates that employee education and training might be able to increase the employee's intrinsic motivation, thereby increasing his effort level and reducing the issue of moral hazard.

Asymmetric information is a key driver of P–

A problems, the simplest being that the agent is unaware of the principals objectives and training can mitigate this effect by clarifying the objectives of the agent. However, information asymmetry is often more problematic in the opposite direction, for instance when the cost of monitoring the agents actions by the principal is high. When the action of the agent is hidden from the principal the agent is then free to optimize their utility subject to their own preferences. If the agent chooses to adhere to the objectives of the principal, even if this appears to require more costly effort than they would need to provide given the incomplete monitoring, then the agent must have some intrinsic dimension of their preferences that drive their optimal choice of action. This is often referred to as an emotional rather than financial reward.

Another dimension to training is that it affords the opportunity for the agent to increase their value in the labour market by signaling the value of their human capital. This will be a function of the relative level of difficulty involved in completing the training. For this to have an effect on the agents effort, there must be an interaction of effort and difficulty within the agents utility function.

A natural CARA utility function that accounts for the effects above is the following one:

$$u = W - e^{-r(\alpha + \rho)(a + \epsilon) + \beta + \gamma\delta a - (1 + \delta)a^2} \tag{10}$$

The utility function in (**??**) includes several additional parameters over (**??**), together with the terms directly relating to the monetary rewards. In detail, ρ captures the level of emotional satisfaction that is fostered by the employee's sense of responsibility or altruism. Casadesus-Masanell[?] and Schmidt[?] outline a theory that the agent who develops this emotional attachment might care for the principal's objectives and be willing to act in the principal's best interest, even if the direct rewards do not correlate to optimal effort.

The cost of psychological or cognitive effort entailed by undertaking the job is captured by the term $-(1 + \delta)a^2$: we follow the norm within this area of literature by assuming that cognitive cost is quadratic in effort as advocated by Bénabou and Tirole[?] amongst others. The parameter δ captures the feeling of 'burden' for the employee, a perception of the 'difficulty' of the job.

A high δ also indicates that the job, in all likelihood, requires substantial skills, hence the higher δ the more potential there is for effort a to be

'transferrable' into skills. Such skills give the worker a better position in the job market. Evidence from the interviews suggest that the harder the employee works the more the training is valuable for future career pathways and this factor shows strongly in the agents stated decision making.

The forward human capital arising from these training activities is captured by the term $\gamma\delta a$. In the seminal contributions by Schultz$^{(?\ )}$ and Becker,$^{(?\ )}$ the transferability of on-the-job training into human capital is generally modeled as being linear or log-linear in effort and difficulty (captured in our scenario by a and δ). Its application in the context of P–A models, and in particular those involving security risk based outcomes, is novel.

In our set-up the factor γ represents the transferability of effort a and burden δ into the worker's additional human capital and can be thought of as a 'rate of forward transferability of effort' (hereinafter, referred to as *transferability*). When $\gamma = 0$ there is no transfer from effort to forward looking human capital and thus no impact on utility.

From (**??**), the employee's certainty equivalent payoff is given by

$$\begin{aligned} \pi_a &= (\alpha + \rho)a + \beta + \gamma\delta a - (1+\delta)a^2 \\ &\quad - \tfrac{1}{2}r\sigma^2(\rho + \alpha)^2. \end{aligned} \tag{11}$$

By following the same procedure used with the benchmark model, we can identify the optimal contract and joint surplus. Let ρ^* be an auxiliary function that captures the reduced level of personal satisfaction when one discounts for both the risk contribution $2r\sigma^2$, as in (**??**), and the additional effort $1 + \delta$ that is required from the employee:

$$\rho^* = \frac{1+\rho}{1 + 2r\sigma^2(1+\delta)} \tag{12}$$

We can now compactly represent the optimal contract and surplus for our training model and this leads us to Proposition **??**.

PROPOSITION 3: The optimal contract and joint surplus when motivation, burden and transferable human capital are included, is defined by:

$$\alpha^* = \rho^* - \rho \tag{13}$$

$$\beta^* = \tfrac{1}{2}r\sigma^2(\rho^*)^2 - \tfrac{1}{4}\frac{(\gamma\delta + \rho^*)^2}{1+\delta} \tag{14}$$

$$a^* = \tfrac{1}{2}\gamma + \tfrac{1}{2}\frac{\rho^* - \gamma}{1+\delta} \tag{15}$$

$$\pi_p^* + \pi_a^* = a^*(1+\rho) + \tfrac{1}{4}\frac{(\gamma\delta)^2 - \rho^*(1+\rho)}{1+\delta}. \tag{16}$$

Proof. See Appendix: Proof of Proposition **??** □

4.3 Agent's overall predicted behavior

We now summarize the direction of changes in the equilibrium contract via the following four claims about the agent's behavior predicted by our extended model.

Claim ?? As either risk aversion r or uncertainty σ^2 increases, i.e., as the employee's risk perception increases, the power of the incentive scheme α^* decreases. This in turn reduces the employee's effort level and total surplus, driving them further away from the best outcome for the principal.

Claim ?? The increase in the emotional satisfaction, ρ always increases the effort. However, the marginal effectiveness of motivation decreases more than linearly with burden δ. It also results in the reduction of the need for the incentive scheme α^*, since monetary rewards can be substituted by emotional satisfaction ($\alpha^* = \rho^* - \rho$).

Claim ?? The transferability rate, γ does not impact the incentive rate α^* because the former only affects the employee and not the principal, which has only an indirect interest in it. However, as γ increases, the effort level and total surplus also rise closer toward the first best outcome. In contrast, β decreases with it, as the principal would extract part of the future expectations on future employability due to better skills by offering a lower present salary.

Claim ?? The direction of the effect of changing the degree of 'burden' of work effort for the agent, δ, on the optimal level of effort a^* depends on the mutual relationship between transferability, γ, emotional satisfaction ρ and the product of risk aversion and actual risk $k = r\sigma^2$. If transferability of effort γ is sufficient by large (unambiguously sufficient if γ is larger than $1 + \rho$) then effort will be increasing for all values of δ albeit the marginal contribution would decrease to zero asymptotically in δ. For a lower value of γ, there is a tipping point as δ varies such that when γ is sufficiently small then decreasing the burden δ would increase effort.[6]

Appendix **??** provides formal explanations of the

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[6] For example, if $\gamma \geq 1 + \rho$ then effort always increases with burden δ. In contrast, if $\gamma \leq \tfrac{1}{2}(1 + \rho)$ and $k \leq 1$, then decreasing burden increases effort.

optimal α and a for the presented models with various scenarios for the parameters. For completeness it includes three additional claims on the equilibrium contract which further elucidate the model outcomes.

A first important observation from the above claims, is that the personal satisfaction (or sense of responsibility/emotional investment), acquired by the employee after the training, positively impacts the overall surplus, acting as a multiplier of the effort. This is discounted more heavily than the transferability factor by the burden imposed for performing the activity. Therefore, a principal needs to exercise caution when adjusting the burden of work, if she is relying on personal satisfaction as a mechanism of aligning incentives, something that is inherently difficult to measure directly.

Indeed, when the employee's feeling of burden, δ, is very high, the employee's effort level, a^*, depends only on the level of transferability of effort to human capital, γ (i.e., $\lim_{\delta \to \infty} a^* = \gamma/2$). Even if difficulty or risk of the activity are very high, the employee will still exert effort as long as γ is positive. After a certain threshold for δ, the incentive factor α^* will become negative (i.e., $\lim_{\delta \to \infty} \alpha^* = -\rho$) which means that the principal will have to resort to fines and punishments rather than positive incentives.

The overarching conclusion of this analysis is that a principal planning the training of her agents should consider adapting the level of 'difficulty' of the job (by reducing the burden through training and technology or opposedly by increasing cognitive load by broadening roles) to the appropriate level of personal motivation or transferability of skills achieved by the employees, in order to obtaining the maximum from its employees. To correctly predict the impact on effort of a change in conditions, the principal needs to identify on which side of the tipping point they are. Whilst the specific claims are not surprising in retrospection, the model provides a very specific categorization of the various effects and their underlying drivers as well as the relative speed of adjustment.

5. QUALITATIVE RESEARCH METHODS

Calibration and validation of a P–A based model represents a significant challenge due to the variety of factors affecting the multifaceted relationships between the various actors. In many cases agency costs have only been identified ex-post after some significant event has uncovered their existence.[?,?,?]

Traditionally, empirical studies using regression analysis are the preferred method of choice for fitting linear (or log-linear) P–A models to data. For example, see the works by Fitoussi and Gurbaxani,[?] for a study on outsourcing, and Knoke and Kalleberg, for a study on training in US organizations.[?]

Unfortunately, several prior studies have indicated that pursuing traditional regression analysis may be misleading when an appropriate statistical model is difficult to implement (e.g. the theoretical model does not have a tractable Markovian representation for econometric identification) or data is simply not available. A pure frequentist approach to risk modeling without due care of the conditions under which the data was generated may lead to inappropriate policies being enacted. Kaufmann[?] and Cramer and Thrall[?] identify the problem of threat inflation in the interpretation of frequentist data on terrorist attacks. Brown and Cox[?] argue that, without proper conditioning of attack data against appropriate controls, the very fact that the decision to attack is endogenous to the target choices means that a probabilistic risk assessment will be unable to provide meaningful insight for forward looking policy. The first issue leads to over-investment in the presence of threat inflation and the second, may increase the chances of a catastrophic security failure.

Empirical studies based on qualitative methods for analyzing P–A relationship, are less frequently used in the literature. Some recent studies have attempted to identify incentive structures from first principles in a similar manner to our own approach. For example, Lin and Chang[?] have studied the key factors of aviation insurance for Taiwanese airline carriers, whilst Kantor and Boros discussed the analysis of cargo screening procedures for contraband detection with a game theory approach.[?]

Whilst qualitative mapping of the theory does not provide directly quantifiable results, the identification of trade-offs and domains of solutions is a useful step in understanding the resultant risks associated with P–A problems. In absence of statistically reliable data, the combination of a quantitative model with qualitative evidence may be the best alternative available to decision makers.

Our contribution is to fill this gap by mapping the results of a quantitative model to the on-the-ground experience of key stakeholders in airport security through a series of semi-structured interviews. In designing a qualitative study of this type, Yin[?] considers three features: a topic, a data collection method, and a source of data.

To determine the topic, we started identifying promising general issues from the thematic analysis of preliminary data we collected during several meetings with aviation industry experts and workshops with airport stakeholders, with the support of introductory interviews and exploratory questionnaires, properly designed to arouse broad subject matters.[?] This first collecting phase allowed us to narrow the focus of the research into the role of security staff in airports and the interplay between regulations, employment strategies, types of training and effective security.

To collect the data, we selected the focused interview method outlined in Merton et al.[?] focusing on a topic of conversation determined in advance, in the attempt to collect reactions and interpretations in a relatively open form. Interviews were conducted in a semi-structured form and in a conversational mode, starting each interview using so called 'grand tour' questions as discussed by Brenner.[?] We prepared a further list of 6-7 questions, which depended on the interviewees responses; the list was circulated to the participants one week before the interviews to make them aware of the type of questions that would be asked. These questions are reported at the end of the Appendix.

As a source of data, we chose interviewees by judgmental or purposive sampling,[?] to capture the variety of roles and activities related to aviation security. A 'gate–keeper', in Yin's terminology,[?] working at Anadolu University provided the introductions and background details for the interviews. Specifically, we interviewed 11 individuals, among them airport security managers, private airport security contractors and government regulators. In Table ?? we provide details on the roles of the interviewees and their institutions. We do not provide their names in order to protect their anonymity. The interviews took place aside two different national workshops organized by the University of Anadolu for civil aviation security stakeholders and have been carried out in separate rooms by the same interviewers. The sampling for the interviews had been set in advance with the support of the gatekeeper. Interviews lasted approximately 30-40 minutes and sometimes a translator attended an interview, ensuring better comprehension by the interviewers and the interviewees. The interviews were audio recorded with the permission of the interviewees and subsequently transcribed. In parallel, hand notes have been taken during the conversation, to collect details and information about feeling, perceptions and preliminary reflections of the interviewers.

6. EVIDENCE FROM INTERVIEWS

In this section we provide an overview of how our stakeholders perceive risk and how the impact of the heterogeneity of risk perceptions impacts airport security in Turkey. Then we explore various agency problems experienced by Turkish airports and apply the results of our model to investigate the effects of the employee's motivations either in terms of increase of forward human capital or sense of responsibility. The final subsection investigates whether a security training program can effectively incentivize the employee to exert due effort, and reduce moral hazard. The answers to our questions illustrate some of the specific channels of agency costs that we have quantified in our model alongside the representative parameters and their domains. It shows that, as the model predicted, an appropriate portfolio of training must include actions that make skills transferable into a forward human capital.

Where we summarize general points put forward by one or more of the interviewees we reference them by use of square brackets, for instance [# 1] to represent the executive director responsible for safety listed in Table ??. Specific quotes are reported in italics with the attribution placed before the quote, once again in square brackets and marked with a colon.

6.1 General Information and Risk Perception

The complex geo-political situation in Turkey is perceived to have an impact on the airport security domain. An important characteristic that the interviewees exhibited was a high level of 'philosophical' alignment with the overarching policy objectives of the principal. The following extracts relate to the institutional and societal factors that can affect security effectiveness.

[# 2]: *"Turkish people are used to be checked with x-ray, even to enter into a mall they are X-ray checked. We want to keep this security measure. [Interviewer: isn't it very expensive?] Sure, but if something bad happens, then it will be more expensive. [...] I do not want anything bad happens [sic]. If you want to travel, you are checked and that is all. If you do not want, you do not travel."*

Most interviewees supported the implementation of a wider detection system in strict collaboration with intelligence services, hoping that

Table IV . Roles of The Participants in the Semi-Structured Interviews.

#ID	Role	Institution	Interview Date
1	Executive director responsible for safety	Airport	Nov 15, 2013
2	Board member for operations and regulation	Airport	Nov 15, 2013
3	Executive director responsible for safety	Airport	Nov 15, 2013
4	Board member for operations and regulation	Airport	Nov 15, 2013
5	Senior manager in charge of training programs	Civil Aviation Authority	Feb 27, 2014
6	Senior manager in charge of training programs	Civil Aviation Authority	Feb 27, 2014
7	Chief of Security Operations	Private Security Contractor	Feb 28, 2014
8	Chief of Security Operations	Civil Aviation Authority	Feb 28, 2014
9	Senior airport manager	Airport	Nov 15, 2013
10	Senior airport manager	Airport	Nov 15, 2013
11	Senior manager in charge of training programs	Airport	Nov 15, 2013

[# 3]: *"Once you arrive at the airport, everything should be already done."*

The perceptions of risk displayed by the stakeholders was somewhat heterogeneous. Prior research on the qualitative evaluation of risk perception indicates that one of the main factors that shapes attitudes towards risk is the trust expressed in the rules governing security. [?] In the course of our interviews, we noted the interviewees' general dissatisfaction on the current security regulations governing airport security; the rules being perceived as weak and incomplete for the purpose of mitigating threats and reducing risks.

[# 1]: *"In the (airport security) regulations, there are few things about practice [that] matters. They are based on regulatory compliance. If you are compliant with a regulation, the government think you are a secure one [sic]. [...] For example, [the government inspects whether] you use the tools that are requested. Yes or no, black or white? But what about the other things?"*

A consensus amongst the interviewees was that regulations list mandatory duties that managers were required to adhere to without substantive added value to the overall level of security.

Another important factor that affects the risk perception is the relationships between the authorities designated for the application of the security rules. [?] The majority of interviewees expressed opinions on the poor cooperation between the various actors involved in airport security, particularly between security staff and police officers.

[# 10]: *"[Police officers] think that the whole department is belonging to them [sic]. They are out of training, they do not have specific info on airport security. [Interviewer: What happens if something happens?] Police takes responsibility on this. [Interviewer: Would it better to*

have only private guards?] No, police is really needed, but educated police."

6.2 Agency Costs and Employment Prospects

The DGCA regularly conduct inspections and security audits on airports in Turkey. Interviewees [# 1, 4, 5, 6, 8, 11] indicated that the purpose is explicitly for monitoring as opposed to information gathering for more general development of security methods. They also pointed out that this monitoring was incomplete. Typically, the DGCA would not be able to perfectly observe actions of all participants including airport employees. A typical P–A approach indicates that a principal will attempt to design a contract that ensures that an agent bears, in whole or in part, the expected costs of shirking. In airport security, however, this might not be entirely feasible.

Risks related to a terrorist events have a high impact, but occur with very low probability. [?] Once a terrorist event occurs, if security personnel are found to be liable then they will not, in all likelihood, be able to provide full ex-post compensation for the damage. Hence the security risk cannot be wholly transferred to the agent from the principal via some form of tort mechanism.

Gross dereliction of duty not-withstanding, the precise chain of events leading to a successful terrorist attack are usually very difficult to reconstruct. It may be impossible to identify the exact point in the security chain where a security staff member has allowed a successful attack to occur, due to their specific reduced effort. [?] The ability of an attacker to gain the information needed for a successful attack may have been collected weeks earlier by observing other agents not correctly performing their task. Together with imperfect monitoring, this can result

in a sub-optimal contract, from the viewpoint of incentive compatibility, between the principal and the agent.

An important counter to the monitoring issue is the very nature of the Turkish job market. Turkey has a large working age population, and many Turkish citizens will accept a job even if the salary places their reservation utility at or close to zero. This implies that the employee, particularly the security staff, perceive a high level of risk to earnings in the job market (i.e., $r\sigma^2$ is high). Our interviewees also stated that employment contracts for security staff in an airport are based on a fixed wage contract (i.e., $\alpha \approx 0$) [# 3, 7], and that this type of job generally attracts workers who only have limited job alternatives (i.e., $\gamma \approx 0$) [# 1, 7]. This finding is similar to other case studies in supply chain security.[?]

[# 7]: *"Payment (for security staff) is very low. For this reason, a lot of [sic] person change job, security persons do not think that this is a very important job. They just come, work little time and then they leave."*

Additionally, interviewee [# 3] presented an argument that most security staff are not aware of the importance of their role and do not feel the responsibility or motivation to conduct the job in a professional manner (i.e., $\rho \approx 0$). The low wages for security staff and quality of employees results in high employee turnover rate [# 1, 4].

[# 1]: *"[G]uys working for these security companies (in an airport) have no other choices for working so they have to work there if they want to earn money, but the problem is that they are not motivated enough."*

This is consistent with the interpretation of (??), where low levels of monetary and non-monetary incentives and high level of the employee's perceived risk result in a lower than optimal levels of effort.

As previously stated, the airport as a private organization and the DGCA as a public body have complex liability sharing arrangements. One interviewee [# 6] clarified that airport operators are responsible for any damage from a security related event. Operators will then entrust some of their risks to their employees. Yet, if the employees are compensated with low wages, society at large will be liable for the whole costs of a security failure.[?]

The costs associated with P–A effects is often found to increase when opportunities to switch employment are high. As such, the degree of human capital invested by the agent in his current position is therefore quite low. It should be noted that some security activities (e.g., liquid detection) are relatively easy to monitor as technology has automated many of these types of processes; and, as such, staff only need to respond to an alarm, rather than engage in costly cognitive effort to ensure the efficacy of the ongoing security operation. Some security activities (e.g., X–Ray screening) still require substantial cognitive and, in some cases, physical effort and for many cases monitoring the employees' actions is either expensive or, indeed, logistically impossible.

6.3 Roles and Responsibility vs Compensation

There is substantial evidence from prior literature that the mix of compensation, fixed versus performance related, is a driving factor in the effort exerted by agents.[?] For example, in aviation security highly qualified workers will only be attracted by high incentives. The corresponding evidence can be found in a report published by U.S. General Accounting Office.[?] According to the report, one of the main reasons that airport screeners do not perform their work properly is the low compensation as it prevents an airport from hiring and retaining qualified workers with high intrinsic motivation.

The perception of interviewees in the Turkish case, [# 1, 3, 7], indicated that the level of pay, compared to other service workers, is not expected to change significantly in the near future, although some recent modest increases have been noted. However, some previous studies have indicated that motivating employees by increasing their intrinsic preferences can improve the gap in optimal effort that may have been perceived between the principal and the agent.[? ? ?]

Our interviewees identified differences in intrinsic motivation between airport staff and police, recalling the earlier comments on cooperation. The cultural role of the police within Turkish civil society was indicated to be an important driver of this sense of civic responsibility and hence reduced the agency costs we have previously identified. This appeared to have a negative impact on the security staff who perceived a degree of exclusion from this culture.

[# 1]: *"Security staff just help the police and they only have limited responsibility because the responsibility is taken from the state security department (i.e., the police). Since the department do not have enough police officers, airport security staff are needed as well."*

Uniformly, the interviewees noted that police officers are working directly for the government and follow a different statute and culture [# 3, 7]. They have more power and responsibilities [# 3], and airport operators have not the right to audit them because they are directly employed by the state [# 7]. Yet, airport police officers are not specifically trained for airport security [# 2, 3] and furthermore, they do not have a security training program specifically designed for them in respect of aviation security.

[# 2]: *"Police officers working near the Syrian boundaries have to be really very careful about possible terrorist attacks; they work there and then after 3 years they come to our airport and they behave the same. This is not good because the context has changes, [it] is really different...They read the regulations we have, but they do not know which is the difference between should/would/must/could."*

In contrast, airport police officers have more responsibilities than airport security staff. When there is a security event, security staff need to report to the police and the police 'have the final responsibility' as paraphrased from comments by [# 1, 3, 7, 10]. One of our interviewees provided a qualitative summary of the ordering of responsibility between airport security staff and the police:

[# 3]: *"Security people have some responsibilities but police has more responsibilities, so security people are quite happy for this [sic]. If they find something risky in the bags, you [security staff] call the police and they [police] have to manage it"*

Police officers seem to feel responsible for airport security. Furthermore, they have a higher fixed wage than security staff [# 7]. The police service can, therefore, attract better qualified and possibly motivated applicants. In the terminology of our motivation and training model, the burden of training δ would be very low whereas a police officer's feeling of responsibility, ρ, would be higher than zero.

Therefore, even if police officers' salary is based on a fixed wage (i.e., $\alpha \approx 0$), they might exert a positive level of effort which can mitigate some moral hazard problem. From (??) their optimal effort level can be regarded as $a = \frac{\rho}{2}$ with $\alpha = 0$. Yet, a common feature of the interviewees' interaction with law enforcement was their perception that the expertise of the police and, in some cases, their motivation were very low.

[# 2]: *"They should have an appropriate and suitable training to do the security at the airport, and this training is different from the training required for the Syrian boundaries."*

As a result, it is unclear whether the increased effort level due to higher ρ can effectively increase the social surplus. An alternative explanation is that their effort may be linked to transferable value from effort. Police often change duties and agglomerate experience and know-how. In some cases, this may prove valuable in their future career and as such exhibiting greater effort provides direct utility to them via the standard rational utility maximization mechanism ($\gamma > 0$). In other cases, exercising effort may not make sense ($\gamma = 0$):

[# 7]: *"The problem is that they change, they do not know what airport security is. Sometimes in 6 months they change role twice. They change job position very often, they are not trained on the civil aviation security. In 6 months it could happen that they have to change 3 times their job."*

Since security expertise is scarce, interviewees stated that most staff need to be trained from scratch which incurs additional significant costs.

[# 1]: *"We have good security devices. However, there are not enough security training agencies in Turkey particularly specialized in aviation security. They are not efficient, so even if we had more money to invest, it would be difficult to find a good training. Training is mandated but not enough. We have to pay for further training...[It is] very difficult to train them. This is a general problem in Turkey, they do not earn a lot of money; but, they do a very critical job."*

As previously indicated, the payment scheme for security staff is based on a fixed salary β and the incentive rate for exerting effort is quite weak (i.e., $\alpha \approx 0$). The current approach targets raising fixed salaries. The primary driver behind their rationale is that with higher salary there is a positive movement in the agents motivation (i.e., $\rho > 0$) and the employees will subsequently exert more effort and that this effort may be more effective in mitigating security threats.

[# 7]: *"[...] security personnel has a big responsibility. So last year, we decided to raise their salary and now we pay them more. The situation now is better."*

However, many airports in Turkey are not able to afford the additional costs associated with this increase in salary, and tend to depend on security training offered by DGCA attempting to raise the employee's intrinsic motivation. The interview results indicate that most of the interviewees

believe that security training can remedy incentive compatibility problems. This is also argued in the literature.[?]

[# 3]: *"You cannot easily change the physical environment but you can change people. So we have to improve training (and) people's vision [...] If you are better trained you feel more confident [even] if you are badly paid"*

From the perspective of the quantitative analysis, a personalized record of training permits the agent to 'deepen' their personal human capital, $\gamma > 0$ and increase motivation $\rho > 0$.

6.4 General and Technical/Specific Training

As explained in §**??**, in Turkey, most of the security training programs are designed and provided by the DGCA. There are also private agencies that provide training programs, particularly for more specific security technologies, but training programs provided by the state are the main source of staff development for those employed in an airport. According to the interviewees, the quality of private training programs was usually better than the quality of programs offered by the state. However, private training is less widely used since it is more expensive [# 7, 10]. Therefore, we focus our exploration only on training programs offered by DGCA, with some limited reference to extra training programs, such as those offered by IATA and documented in Table **??** of §**??**.

The interviewees indicated that the security training is effectively the same for all airports no matter the size.

[# 6]: *"We have training for all people involved in the airport security, as this personnel could be a potential threat to the security of the airport. [sic] In airport every person has a role and a duty in aviation security, so we need to train all of them in order to provide total security. We have to train them in aviation security procedures, national and international as well."*

The interviewees provided further details on training programs along with the classification we have illustrated in §**??** (Table **??**): 'general' and 'technical'. From the interviewees, the former aims at providing efficiency that ensure the achievement of a firm's general business objectives (i.e., general security training). Training with a technical approach (i.e., technical/specific security training) intends to properly address the needs for specific security operations (e.g., IATA and ICAO requirements for hazardous substance recognition and X-ray screening

operations). As indicated in §**??**, this type of training generally offers a certificate of performance which might provide a forward looking value to employees in a job market.

Three security training modules were singled out by the interviewees among those mandated by the regulator [# 6, 11]. Module 1 is security awareness training that is mandatory for all attendants, staff and managers in an airport. Modules 2 and 3 are for training security staff; this includes X-ray and metal detector operators and cabin crew.

While the main objective of Module 1 is to transfer ubiquitous security knowledge (required for all staff) and to clarify the importance of airport security (the specific objectives of the principal) and, by construction, increasing security awareness; Modules 2 and 3 focus more on transferring specific knowledge for certain security work. According to interviewee [# 11], Modules 2 and 3 are compulsory and are more specific compared to Module 1. Every airport in Turkey has to follow the procedures for Modules 2 and 3 very precisely. It was further noted that Modules 2 and 3 require more resources and information for training. Interviewee [# 5] also stated that, while DGCA does not have any different implementation procedures for security awareness training, it does have specific training programs for educating the personnel working in different roles.

[# 5]: *"Security awareness training is for everyone in the airport because it is an indispensable part of airport security. On the other hand, training implementation has to be different for different roles; you cannot implement the same rules for cabin crew and ground service people or screening staff in security check points."*

As such, employees have differentiated training depending on their duties. Training varies from person to person, and from department to department.

General security training programs are provided in a classroom environment and this form may not be very effective [# 10,11].

[# 11]: *"[General] Training, as it is, is boring, people are not motivated to follow it. They learn more while working. Time is short and lessons are boring. It is not very effective."*

Linking these observations with our motivation and training model, training for general knowledge transfer of security might only incur a burden on the employees (i.e., $\delta > 0$) and will not provide the employees with the recognition of their role in ensuring airport security (i.e., $\rho \approx 0$) as indicated by interviewee [# 11].

An alternative explanation could be that general security training modules were badly designed. Yet, none of the interviewees singled out the trainers for criticism. As interviewees have been often brutally honest even in criticism of other officials (e.g. police officers or even regulators approach to security and compliance), we believe they would have raised the issue at some point. Quality is likely a non-issue because there is a close mapping between DGCA modules and IATA modules, as we shown in Table **??**. Training on IATA modules is expensive and typically one or two members of a security team take the IATA modules and then implement the local modules to the various regional airport security teams. The IATA modules are used in every country including the G7 and emerging economies. So a defective general security training module in the IATA syllabus would be quickly remediated and there is evidence of this syllabus development from cursory analysis of the historical copies of the IATA and DGCA handbooks.

Consequently, while general security training is indispensable for enhancing security awareness as discussed by interviewee [# 5], it is unhelpful to increase employees' motivation and thus to reduce moral hazard. General security training does not provide a specific certification to a qualified trainee and does not require an exam. Employees only need to retake a training program once in every 3 years. This implies that the general security training does not provide any information on the employee's repute and does not increase his level of employability (i.e., $\gamma \approx 0$). Consequently, general security training might not be helpful to increase employees' motivation and to reduce moral hazard (i.e., $a \approx 0$) — indicated in Claim **??** in the Appendix. Indeed, this is common impression some of the interviewees have expressed about general security training.

We now consider the effectiveness of a training program aiming at transferring specific technical knowledge (i.e., technical/specific security training). A training manager [# 11] explained that Modules 2 and 3 are carried out by on-the-job training and practical exercises as well as classroom lectures. This approach was deemed to be very effective in motivating trainees and in attaining skills (i.e., $\rho > 0$) notwithstanding the higher burden on the trainees than a general security training program (i.e., $\delta > 0$).

The other facet of technical/specific security training is the mandatory renewal of employees certification and the possible loss of the job due to a failure of renewing one's certification [# 5,

6, 11]. In Turkey, security staff need to retake Module 2 and Module 3 every 2 years to renew their certification. This is accomplished through an examination conducted by the Training Department of Aviation Security. If they cannot pass the exam, they can no longer work for an airport.

[# 7]: *"When we are selecting persons, we use a lot of criteria. [...] we need to know whether X-ray operators are able to use that technology, so we need to have an examination, because probably they have no experience."*

We can interpret technical/specific security training as providing a degree of transferable value from effort. This type of training provides certification and expertise that can be used for later employment. The interviewees indicated that in a tough job market this is an 'undeniable asset' [# 9, 11].

[# 7]: *"There is a special team for checking [...] We want to know their experience, if they have been working for at least 3 years and then we evaluate them. If the level if very low we do not hire them. Since our salary is higher than others, there are a lot of people that want to work with us. For these reasons, when we are selecting persons we use a lot of criteria."*

From our analysis in §**??**, the optimal effort level is $a = \frac{\gamma \delta + \rho}{2(1+\delta)}$. From inspection we can see that this is always greater than the optimal effort level without monetary and intrinsic incentives. Furthermore, even if the employee's feeling of burden is very high, the training can still lead to a positive level of effort (i.e., $a = \frac{1}{2}\gamma$) as long as the level of transferability has a positive value ($\gamma > 0$).

A core conclusion appears to be that general security training develops employees' feeling of responsibility and understanding of the rationale behind their tasks, but mitigates a moral hazard problem only in part. It becomes increasingly less effective as a the burden increases. Transferability of value from effort, i.e. learning technical skills that are important for job retention, appears to be an important factor in the employees pay-off function.

7. CONCLUSIONS

Prior studies of *ex post* failings in complex socio technical systems (either security events or accidents) have often demonstrated the causal link between misalignment of incentives and catastrophic failures. For example, Suzuki describes an after-the-fact summary of the agency costs associated with moral hazard and information asymmetry for nuclear safety in Japan.$^{(?\ )}$

Our approach seeks to identify P–A issues *ex ante* to help reduce the likelihood of security failures by elucidating to a policy maker (the principal) the risk structures that they are facing and the possible mechanisms behind the decision making process of security officers (the agents) acting on its behalf. The key methodological contribution is the combination of a quantitative P–A economic model with a qualitative case study to validate the outcomes suggested by the model.

We have used this approach to disentangle the issues behind the different choices of security training available for the personnel in charge of airport security. Our initial model specification mimics the typical setting with only fixed or varying monetary rewards. Our second model, incorporates trade-offs in welfare that includes incentives in terms of 'intrinsic motivation', such as understanding and feeling responsible for the achievement of the security goals of the principal (the airport security authority). We have then included additional factors in terms of effort, cognitive and physical burden, and possibility for the training to yield additional transferrable skills to the security officers (a form of forward human capital leading to better job prospect into the future). Our quantitative findings have been validated by a qualitative study conducted on security staff operating in an airport in a high risk geographical setting (Turkey).

For tractability and ease of exposition, our risk generating mechanism assumes a 'non-strategic' exogenous attacker. Incorporating attacker externalities as either a sub-game or as a simultaneous equilibrium would be the obvious extension to our theoretical model. From a practical perspective such extension would not be needed, as targeted attacks exploiting security lapses due to agency issues would in general be more successful, magnifying the costs of the effects we have identified.

Our quantitative and qualitative findings demonstrate that risk mitigation measures should account for the marginal effects of risk aversion, marginal transferability of effort & cognitive load and the basic burden of effort. This is quite an attractive decomposition and can lead to the following effects that must be considered by the risk analyst designing a security training portfolio for staff:

- a better motivated worker may do more (the ρa term dominates the payoff) until the cognitive effort in training and actions becomes too burdensome (the δa^2 term dominates);

- a skilled worker may do more with less effort, as the increase in burden due to training is over compensated by the easiness of performing the job (so that globally the value of δ decreases);
- a more skilled worker may work harder as his or her skills increases (the $\gamma \delta a$ term dominates), as this improves the expected pay-off in terms of ongoing and future employability.

Each effect may dominate the other depending on the environment. Given the current salary structure for security officers working in airport security (lower than average salary in a difficult job market), our preliminary evidence suggests that security training which builds human capital by providing certification-based evidence of competencies dominates security training primarily aimed at increasing intrinsic motivation.

As we mentioned, our approach cannot be used to make point predictions. Yet, it allows the risk analyst to understand trends and effects of varying security measures and incentives, and to validate them with domain experts, framing their anecdotal evidence into a coherent and mathematically sound picture. It is a valuable approach to risk analysis when data is severely limited and controlled experiments are ethically impossible.

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APPENDIX

A Proofs of Propositions

Here we provide the proofs of the propositions and the claims presented in §**??**. It is intended to be an electronic supplement.

As a preliminary result we derive the certainty equivalent forms found in Equations (**??**) and (**??**). Suppose that the risk averse employee has an exponential utility function $u_a = -e^{-rw}$, where $w = s(x) - a^2$ and $w \sim \mathcal{N}(\mu, \sigma^2)$. The corresponding density function for w is given as

$$f(w) = \frac{1}{\sigma\sqrt{2\pi}} e^{\left(-\frac{(w-\mu)^2}{2\sigma^2}\right)}.$$

Therefore, the expected utility can be defined as

$$
\begin{aligned}
\mathbb{E}[u_a] &= -\mathbb{E}[-e^{-rw}] \\
&= -\int_{-\infty}^{\infty} e^{-rw} \frac{1}{\sigma\sqrt{2\pi}} e^{\left(-\frac{(w-\mu)^2}{2\sigma^2}\right)} dw \\
&= -\frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{\left(-rw-\frac{(w-\mu)^2}{2\sigma^2}\right)} dw.
\end{aligned}
$$

Noting that

$$
\begin{aligned}
&-rw - \frac{(w-\mu)^2}{2\sigma^2} \\
&= -rw - \frac{(w-\mu)^2}{2\sigma^2} + r\mu - r\mu + \frac{r^2\sigma^2}{2} - \frac{r^2\sigma^2}{2} \\
&= -\frac{1}{2}\left(2r(w-\mu) + \frac{(w-\mu)^2}{\sigma^2} + r^2\sigma^2\right) - r\mu + \frac{r^2\sigma^2}{2} \\
&= -\frac{1}{2\sigma^2}((w-\mu) + r\sigma^2)^2 - r\mu + \frac{r^2\sigma^2}{2}.
\end{aligned}
$$

From this, we can see that

$$\mathbb{E}[u_a] = -\frac{1}{\sigma\sqrt{2\pi}} e^{\left(-r\mu+\frac{r^2\sigma^2}{2}\right)} \int_{-\infty}^{\infty} e^{\left(-\frac{y^2}{2\sigma^2}\right)} dw$$

where y denotes $((w-\mu) + r\sigma^2)$. Since

$$g(y) = -\frac{1}{\sigma\sqrt{2\pi}} e^{\left(-\frac{y^2}{2\sigma^2}\right)}$$

is the probability density function for random variable y which has normal distribution with mean 0 and variance σ^2, and therefore

$$-\frac{1}{\sigma\sqrt{2\pi}} \int_{-\infty}^{\infty} e^{\left(-\frac{y^2}{2\sigma^2}\right)} dy = 1,$$

we obtain

$$
\begin{aligned}
\mathbb{E}[u_a] &= -\frac{1}{\sigma\sqrt{2\pi}} e^{\left(-r\mu+\frac{r^2\sigma^2}{2}\right)} \int_{-\infty}^{\infty} e^{\left(-\frac{y^2}{2\sigma^2}\right)} dy \\
&= -e^{-r\left(\mu+\frac{r\sigma^2}{2}\right)}.
\end{aligned}
$$

From the certainty equivalent theorem, $u(\pi_a) = E[u_a]$. We therefore get

$$\pi_a = \mu - \frac{r\sigma^2}{2} = \mathbb{E}(w) - \frac{rVar(w)}{2}.$$

Since $w = s(x) - a^2 = \alpha(a+\epsilon) + \beta - a^2$, the agent's certainty equivalent is given as

$$\pi_a = \alpha a + \beta - a^2 - \tfrac{1}{2}r\alpha^2\sigma^2.$$

The government is risk neutral and has net benefit $u_p = (1 - \alpha)(a+\epsilon) - \beta$. Therefore, the government's expected net benefit can be defined as

$$\mathbb{E}[u_p] = a - \alpha a - \beta.$$

Since $u(\pi_p) = \mathbb{E}[u_p]$, the government's certainty equivalent is

$$\pi_p = a - \alpha a - \beta.$$

Proof. [Proposition **??**] If the employee's action is observable without costs, the government does not need to take an incentive compatibility constraint into account, and only needs to pay the employee for his action that can guarantee his participation. Hence, the employee's participation constraint holds with equality, and we set the employee's reservation utility equals to zero (i.e., $\pi_a = 0$). The government's problem is then to solve the following maximization problem.

$$\max_a \pi_a + \pi_p = \max_a a - a^2 - \tfrac{1}{2}r\alpha^2\sigma^2. \tag{A.1}$$

It entails the employee to make the level of action $a^\dagger = 1/2$. Inserting this value into the joint surplus and maximizing it with respect to α yields $\alpha^\dagger = 0$. Using $a^\dagger$ and $\alpha^\dagger$ in the participation constraint, we get $\beta^\dagger = 1/4$ which equals to the cost of his action. Consequently, the government gets net benefits of $1/4$.

Proof. [Proposition **??**] In order to identify optimal α and β, we first need to explore the employee's problem. Since his problem is to identify an optimal effort level that can maximize π_a for given α and β, it can be denoted as $\max_a \pi_a$ and gives the first-order condition $a^\ddagger = \alpha/2$.

Therefore, if incentive wage is not provided (i.e., $\alpha = 0$), the employee will not carry out any action (i.e., $a = 0$). This condition shows that an optimal action level is only determined by an incentive rate α. Moreover, the condition also means that the employee's marginal benefits of action (i.e., marginal expected reward) are equal to his marginal costs of action.

By inserting optimal effort level $a^\ddagger = \alpha/2$ into (**??**), we can drop the incentive compatibility constraint and rewrite it as:

$$\max_\alpha \frac{\alpha}{2} - \left(\frac{\alpha}{2}\right)^2 - \tfrac{1}{2}r\alpha^2\sigma^2. \tag{A.2}$$

This problem has the first-order condition $1/2 - \alpha/2 - r\alpha\sigma^2 = 0$. Rearranging this equation with respect to α gives

$$\alpha^\ddagger = \frac{1}{(1 + 2r\sigma^2)}.$$

Inserting this value into $a^\ddagger = \alpha/2$ and (**??**) clearly yields

$$a^\ddagger = \frac{1}{2(1 + 2r\sigma^2)}$$

$$\pi_p^\ddagger + \pi_a^\ddagger = \frac{1}{4(1 + 2r\sigma^2)}.$$

Furthermore, inserting $\alpha^\ddagger$ and $a^\ddagger$ into $\pi_a^\ddagger$ and setting this to

0 yields equation (**??**) below.

$$\beta^{\ddagger} = \tfrac{1}{4}\alpha^2\left(-1 + 2r\sigma^2\right) = \frac{2r\sigma^2 - 1}{4(1 + 2r\sigma^2)^2}.$$

Proof. [Proposition **??**] When the intrinsic incentives are taken into account, in the first stage, the employee chooses his action a for the given satisfaction ρ, burden δ and returns from the burden γ. Therefore, his problem is to decide an effort level a, such that π_a^* is maximized for given α, β, ρ, δ and γ: $\max_a \pi_a^*$. The optimal effort therefore is

$$a^* = \frac{\alpha + \gamma\delta + \rho}{2(1 + \delta)}. \tag{A.3}$$

This implies that the employee who has developed a positive level of ρ is willing to exert a strictly positive amount of effort even if there is no monetary incentive, α. A positive level of γ will also increase the employee's effort level, if he bears some psychological burden (i.e., $\delta > 0$).

The government's certainty equivalent is identical with (**??**). Inserting (**??**) into the joint surplus and writing it as a maximization problem with respect to α yields

$$\max_{\alpha} \frac{-(-2+\alpha)\alpha + (\gamma\delta+\rho)(2+\gamma\delta+\rho)}{4(1+\delta)} - \frac{2r(1+\delta)(\alpha+\rho)^2\sigma^2}{4(1+\delta)}.$$

The first order condition therefore is

$$\frac{1-\alpha}{2+2\delta} - r(\alpha+\rho)\sigma^2 = 0,$$

and rewriting this gives the optimal incentive rate as a function of the employee's burden and satisfaction:

$$\alpha^* = \frac{1+\rho}{1 + 2(1+\delta)r\sigma^2} - \rho. \tag{A.4}$$

Inserting this into (**??**) yields the agent's optimal effort with

$$a^* = \frac{1 + \rho + \gamma\delta(1 + 2(1+\delta)r\sigma^2)}{2(1+\delta)(1 + 2(1+\delta)r\sigma^2)}. \tag{A.5}$$

Re-arranging terms and splitting the fraction yields the desired value.

By setting (**??**) to zero and substituting a with a^*, the fixed wage β^* as a function of α^* can be given as:

$$\beta^* = \tfrac{1}{2}(\alpha^*+\rho)^2 r\sigma^2 - \frac{(\alpha^* + \gamma\delta + \rho)^2}{4(1+\delta)}$$

The total surplus from taking into account intrinsic incentives can be written as:

$$\pi_p^* + \pi_a^* = \frac{(1+\gamma\delta+\rho)^2 + 2\gamma\delta(1+\delta)(2+\gamma\delta+2\rho)r\sigma^2}{4(1+\delta)(1+2(1+\delta)r\sigma^2)}. \tag{A.6}$$

Algebraic rearrangement and substitution of ρ^*, a^* and α^* provides the required result.

B Sensitivity Analysis

The following statements show the results of sensitivity analysis for the optimal values listed in §**??**. For simplicity of exposition, we denote $k = r\sigma^2$.

CLAIM 1:   An increase in k results in $\partial\alpha^*/\partial k < 0$, $\partial a^*/\partial k < 0$ and $\partial(\pi_a^* + \pi_p^*)/\partial k < 0$.

The proof proceeds by cases for each derivative of the optimal values. We suppose $k \geq 0$, $\rho \geq 0$, $\gamma \geq 0$ and $\delta \geq 0$.

(i) The derivative of α^* with respect to k is less than zero because
$$\frac{\partial\alpha^*}{\partial k} = -\frac{2(1+\delta)(1+\rho)}{(1 + 2k(1+\delta))^2}.$$

(ii) The derivative of a^* with respect to k is less than zero since
$$\frac{\partial a^*}{\partial k} = -\frac{1+\rho}{(1 + 2k(1+\delta))^2}.$$

(iii) The derivative of $\pi_a^* + \pi_p^*$ with respect to k is less than zero since
$$\frac{\partial(\pi_a^* + \pi_p^*)}{\partial k} = -\frac{(1+\rho)^2}{2(1 + 2k(1+\delta))^2}.$$

CLAIM 2:   The change in ρ results in $\partial\alpha^*/\partial\rho < 0$, $\partial a^*/\partial\rho > 0$ and $\partial(\pi_a^* + \pi_p^*)/\partial\rho > 0$.

Proof. The proof is divided for each derivative of the optimal values. We suppose $k \geq 0$, $\rho \geq 0$, $\gamma \geq 0$ and $\delta \geq 0$.

(i) The derivative of α^* with respect to ρ is less than zero because
$$\frac{\partial\alpha^*}{\partial\rho} = -\frac{2k(1+\delta)}{1 + 2k(1+\delta)}.$$

(ii) The derivative of a^* with respect to ρ is greater than zero since
$$\frac{\partial a^*}{\partial\rho} = \frac{1}{2(1+\delta)(1 + 2k(1+\delta))}.$$

(iii) The derivative of $\pi_a^* + \pi_p^*$ with respect to ρ is greater than zero since
$$\frac{\partial(\pi_a^* + \pi_p^*)}{\partial\rho} = \frac{1 + \rho + \gamma\delta(1 + 2k(1+\delta))}{2(1 + \delta + 2k(1+\delta)^2)}.$$

Note that it is always $\frac{\partial a^*}{\partial\rho} \geq 0$ and $\frac{\partial a^*}{\partial\rho} = O(\frac{1}{\delta^2})$, and therefore, as $\delta \to 0$, $\frac{\partial a^*}{\partial\rho} \to \infty$ and as $\delta \to \infty$, $\frac{\partial a^*}{\partial\rho} \to 0$.

CLAIM 3:   From (**??**), it can be identified that the change in γ results in $\partial\alpha^*/\partial\gamma = 0$. However, from (**??**) and (**??**), it can easily found that $\partial a^*/\partial\gamma > 0$ and $\partial(\pi_a^* + \pi_p^*)/\partial\gamma > 0$.

The proof proceeds by cases for each derivative of the optimal values. The derivative of α^* with respect to γ is zero because α^* does not depend on γ.

Both the derivative of a^* with respect to γ and the derivative of $\pi_a^* + \pi_p^*$ are greater than zero since

$$\frac{\partial a^*}{\partial\gamma} = \frac{\delta}{2(1+\delta)}, \text{ and}$$

$$\frac{\partial(\pi_a^* + \pi_p^*)}{\partial\gamma} = \frac{\delta(1 + \gamma\delta + \rho)}{2(1+\delta)}.$$

CLAIM 4:   For all values of δ, $\partial\alpha^*/\partial\delta < 0$. For $\gamma \geq 1 + \rho$ the derivative $\partial\alpha^*/\partial\delta > 0$.

The proof proceeds by cases on the partial derivatives.

(1) The derivative of α^* with respect to δ is always less than zero because
$$\frac{\partial\alpha^*}{\partial\delta} = -\frac{2k(1+\rho)}{(1 + 2k(1+\delta))^2}$$

(2) The derivative of the optimal incentive rate a^* with respect to δ is
$$\frac{\partial a^*}{\partial \delta} = \frac{\gamma(1 + 2k(1 + \delta))^2 - (1 + \rho)(1 + 4k(1 + \delta))}{2(1 + \delta)^2(1 + 2k(1 + \delta))^2}$$
The direction of this derivative cannot be determined unambiguously for a^* since it depends on the relationship among γ, δ, k and ρ. To identify the tipping point, fixing $\Delta = 2k(1 + \delta)$ and $\Gamma = \frac{1+\rho}{\gamma}$ were $\Gamma \geq 1$ and substituting for Δ into equations (**??**) and (**??**) yields
$$a^* = \frac{\gamma}{2} - \frac{k\gamma}{\Delta} + \frac{k(1 + \rho)}{\Delta(1 + \Delta)}$$
$$\frac{\partial a^*}{\partial \delta} = 2k^2 \frac{\gamma\Delta^2 + 2(\gamma - (1 + \rho))\Delta + \gamma - (1 + \rho)}{\Delta^2(1 + \Delta)^2}$$
For $\gamma \geq 1 + \rho$ the derivative is always positive for all values of δ. So an increase in burden would always yield an increase in effort if the transferability coefficient is sufficiently large. However, as $\delta \to \infty$ (and hence $\Delta \to \infty$) the effort converges to $\gamma/2$ and the marginal contribution of the burden to effort becomes negligible as the denominator of the partial derivative grows as $O(\delta^4)$ whereas the numerator grows as $O(\delta^2)$.
When γ is less than $1 + \rho$ there is a tipping point in δ such that decreasing the burden increases the effort as the derivative is negative. As $\delta \to 0$ the effort goes to infinity. Solving the equation of the numerator of the partial derivative yields the condition
$$\Delta \leq \Gamma - 1 + \sqrt{\Gamma(\Gamma - 1)} \qquad (B.1)$$
If $\frac{1+\rho}{\gamma} \geq 2$ then $\sqrt{\Gamma(\Gamma - 1)} \geq 1$ and therefore a sufficient condition is $\Delta \leq \Gamma$. Replacing the abbreviations Δ and Γ with their underlying terms yields $\delta \leq \frac{1+\rho}{2k\gamma} - 1$ which is satisfied for $\delta \geq 0$ when $\frac{1+\rho}{\gamma} \geq 2k$ i.e. when $k \leq 1$.

(3) The derivative of the total surplus $(\pi_a^* + \pi_p^*)$ with respect to δ is given by
$$\frac{\partial(\pi_a^* + \pi_p^*)}{\partial \delta} = \frac{\gamma(\gamma\delta^2 + 2\gamma\delta + 2\rho + 2)}{4(\delta + 1)^2} +$$
$$\frac{-\rho^2 - 2\rho - 1}{2(\delta + 1)^2(2\delta k + 2k + 1)} +$$
$$\frac{\rho^2 + 2\rho + 1}{4(\delta + 1)^2(2\delta k + 2k + 1)^2}$$
Similarly to the sub-case for $\partial a^*/\partial \delta$ the direction of the derivative is dependent on the magnitudes of ρ, γ, k and δ itself. However, the calculation of the tipping point is less straightforward. Setting $K = \gamma^2 k^2$ we can rewrite **??** as the following polynomial:
$$\frac{\partial(\pi_a^* + \pi_p^*)}{\partial \delta} = \mathscr{C}(1) + \mathscr{C}(2)\Gamma + \mathscr{C}(3)\Gamma^2$$
where $\mathscr{C}(1) = \frac{1}{4}\gamma^2 - K\Delta^{-2}$, $\mathscr{C}(2) = 2K\Delta^{-2}$ and $\mathscr{C}(3) = K(1 + \Delta)^{-1} - K\Delta^{-2}$.

This polynomial has a positive real root in Γ of $\mathscr{R}(1) = \frac{(\Delta+1)}{2(2\Delta k+k)}\left(\Delta\sqrt{2\Delta + 4k^2 + 1} + 2(\Delta + 1)k\right)$. When $\Gamma = \mathscr{R}(1)$ the derivative of the total surplus is equal to zero and as such this is the critical tipping point after which an increase in δ will, ceteris paribus, lead to an increase in total effort, however when $\Gamma < \mathscr{R}(1)$ total surplus decreases with increasing burden.

C Optimal α and a for different scenarios

We now compare the optimal α and a for different models with various assumptions for the parameters. A series of auxiliary claims are developed.

CLAIM 5: If the incentive rate equals zero ($\alpha = 0$), the optimal effort level for the model with motivations and training might be higher than that in the benchmark model.

From $a^\ddagger = \frac{\alpha}{2}$ in (**??**) and $a^* = \frac{\alpha+\gamma\delta+\rho}{2(1+\delta)}$ in (**??**), we can compare $a^\ddagger$ and a^* for various scenarios. Since $\alpha = 0$, we have

(i) $\rho > 0, \delta = 0, \gamma = 0$: $a^* = \frac{\rho}{2} > 0$.

(ii) $\rho > 0, \delta > 0, \gamma = 0$: $a^* = \frac{\rho}{2(1+\delta)} > 0$.

(iii) $\rho > 0, \delta > 0, \gamma > 0$: $a^* = \frac{\gamma\delta+\rho}{2(1+\delta)} > 0$.

(iv) $\rho = 0, \delta > 0, \gamma = 0$: $a^* = 0$.

(v) $\rho = 0, \delta > 0, \gamma > 0$: $a^* = \frac{\gamma\delta}{2(1+\delta)} > 0$.

The case where $\delta = 0$ and $\gamma > 0$ is omitted since it is unrealistic.

As can be seen, as long as ρ or γ is greater than zero, a positive effort can be exerted. However, if both ρ and γ are zero (i.e., (iii)), a^* becomes zero.

CLAIM 6: If α has a positive value ($\alpha > 0$), the optimal effort level for the model with motivations and training is higher than that in the benchmark model when a level of burden δ equals zero.

This is the case where $\alpha > 0$, $\rho > 0$, $\delta = 0$ and $\gamma = 0$. Since $a^* = \frac{\alpha+\rho}{2}$, it is clear that $a^* > a^\ddagger$.

CLAIM 7: If α and δ have positive values (i.e., Cases 2 to 5), the optimal effort level for the model with motivations and training can only be higher than that in the benchmark model when ρ or γ is sufficiently high.

Since the denominator of a^* in each case is greater than that of $a^\ddagger$ (i.e., $2(1 + \delta)(1 + 2k(1 + \delta)) > 2(1 + 2k)$), the numerator of a^* should be sufficiently higher than that of $a^\ddagger$ to make $a^* > a^\ddagger$.

This claim implies that a moral hazard problem can be mitigated if the employee's level of emotional motivation or forward transferability on his costly effort is sufficiently high. Therefore, in our training example, even if a training program results in a high burden on the employee, it can be very effective in making the employee exert his due care as long as the employee's effort has higher forward transferability on his costly effort.

D Interview Questions

Tables **??** and **??** provide the pro-forma for the questions for the two days of interviews conducted with the stakeholders from Table **??**.

Table D.1. Interview Questions for Round 1

REGULATION

(1) Which are the important security regulations that rule the airport domain?

  (a) Are these regulations applied to every airport, irrespective of its size?

  (b) Which is the authority in charge to design these regulations?

(2) What do you think is the rationale for those security measures? Setting goals, addressing incidents, mandating technology, ecc

(3) When the regulator mandates security investments, does he mandate specific measures OR just generic measures? GENERAL REQUEST $\leftrightarrow$ SPECIFIC REQUEST

  Specific: you must have at least 3 body scanner

  Generic: spend to have less than 3 successful intrusions to the tower

(4) If the regulation is violated, fines are applied? Can you give some examples? Amount? Motivation?

(5) Do authorities prefer to charge security costs on the airport overall budget OR on the passengers flight ticket? COSTS TO BUDGET $\leftrightarrow$ COSTS TO PASSENGERS

(6) The national regulation you applied at Anadolu airport envisages a minimum OR a mandatory set of security measures? MINIMUM $\leftrightarrow$ MANDATORY

  Minimum: you have to do A or more depending on your decision

  Mandatory: you have to do exactly A.

(7) How does your airport address the regulation?

  (a) Do you need (or want) to do something beyond the mandatory rules? Why?

  (b) What about other airports?

AIRPORT MANAGEMENT

(1) If you had some money to invest in security, which measure would be your first choice? And your second? Can you motivate this choice?

(2) Think about a technological recent innovation the regulator asked you to introduce: was it in line with the needs of your airport? Did it really improve the overall security?

(3) Do you think other security measures should be requested and mandated by the regulator?

(4) If the regulator increased the minimum mandatory level, would you prefer to invest more in training OR in technological devices?

(5) If you had additional money to invest for the security of your airport, would you prefer to employ a new (or updated) technological device(s) OR to introduce further training programs? TECHNOLOGY $\leftrightarrow$ TRAINING

(6) If you had additional money to invest for the security of your airport, would you prefer to hire additional staff OR to introduce further training programs? MORE STAFF $\leftrightarrow$ TRAINING

(7) To prevent an attack, would you prefer to improve technological countermeasures OR to (better) develop a manual contingency procedure? TECHNOLOGY $\leftrightarrow$ MANUAL.

  (a) Would you do the same for a cyber-attack?

Note: Question sheet for semi-structured interviews. The interviews took place over the course of 14th and 15th November 2013 at the premises of the Anadolu Airport. Interviews were conducted on a one-to-one basis while a English translator attended in some cases. The interviews were recorded and transcribed. All interviewees were asked to briefly introduce themselves and specify their roles.

Table D.2. Interview Questions for Round 2

AIRPORT MANAGER - TRAINING	AIRPORT MANAGER - SECURITY
(1) Who is responsible for training in your airport?	(1) Who is responsible for security in your airport?
(2) By whom is training provided in you airport? Is a general or a specific training program? Who pays for it?	(2) Can you describe the organizational structure of the security staff in your airport? Which actors are involved? Roles/duties? % decided by whom?
(3) Do you have the chance to decide to whom commit the delivery of training?	(3) Do you have the chance to decide to whom commit the delivery of security services?
(a) If outsourcing: Why do you prefer this solution? Criteria? (Cost efficient, qualified expert personnel, better control, ...) Do you have a preferred provider?	(a) If outsourcing: Why do you prefer this solution? Criteria? (Cost efficient, qualified expert personnel, better control, ...) Do you have a preferred provider?
(b) If insourcing: Why do you prefer this solution? Criteria? If you could outsource, would you do that? Why?	(b) If insourcing: Why do you prefer this solution? Criteria? If you could outsource, would you do that? Why?
(4) The contractual relationship:	(4) The contractual relationship:
(a) How can you evaluate the quality of the outsourced/insourced provided training? Monitoring? (Formal and direct monitoring// informal and infrequent? Why?)	(a) How can you evaluate the quality of the outsourced/insourced provided training? Monitoring? (Formal and direct monitoring// informal and infrequent? Why?)
(b) Is it a long term or short term contract?	(b) Is it a long term or short term contract?
(c) Do you share sensitive information with the outsourced company?	(c) Do you share sensitive information with the outsourced company?
(5) Have you ever experienced conflicts with the outsourced company? Explain?	(5) Have you ever experienced conflicts with the outsourced company? Explain?
(6) Do you think that the training provided is enough? If you had more money, would you improve training?	(6) Do you have an evaluation system for police staff as well?
	(7) Who pays for security in your airport? (state/charges on passengers ticket/airport budget)

AIRPORT MANAGER	PRIVATE SECURITY MANAGER(S)
(1) Do you think that the current regulation related to airport security appropriately fits your airport needs? Do you think that the regulation about security measures is enough?	(1) Which security role does your private security company cover in the airport? Duties? Activities? (Mention at least 2)
(2) Customized vs. uniform regulation: which is more appropriate in your opinion? Why? Explain?	(2) Do you share your everyday work activities with other security agents? Do you have different roles/duties? (How is the interplay with the other security agent managed?)
(3) When the regulator mandates security investments, does he mandates specific measures or generic measures? (you must have 3 X-ray scanners or just you must have .. scanners?)	(3) Do you have a specific training in aviation security? (Different training programs for different security staff? How many hours? Provided by whom?)
(4) Do you need to add additional security measures beyond the mandatory rules?	(4) Is your performance regularly monitored? Are security agents in charge with different roles differently evaluated? How? (Are they monitored on measurable outcomes? (ex: security guards and X-ray inspector should have different performance measures))
	(5) About the contractual relationship:
	(a) Is it a long term or short term contract?
	(b) Does the airport share sensitive information with you?
	(6) Have you ever experienced conflicts with the airport on the management of the security services? Explain.

Note: The interviews took place over the course of 27th and 28th of February 2014 at the premises of the Anadolu Airport. Interviews were conducted on a one-to-one basis while a English translator attended in some cases. The interviews were recorded and transcribed. All interviewees were asked to briefly introduce themselves and specify their roles. The first row of questions aims at collecting data about the decision of outsourcing/insourcing some services like training and security.