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Aviation security: Costing, pricing, finance and performance

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ABSTRACT

This article provides an overview of economic issues pertaining to the costing, pricing, financing and performance of aviation security and an introduction to eight articles contributing to this special issue. Topics include benefit-cost analysis, production and input relationships, information flows, human factors and performance measurement, the role of technology, and risk-based security. We highlight resource allocation and measurement problems that are endemic to aviation security, and analyze the growing costs of aviation security over the last 15 years. We also provide data and analysis on financing that demonstrates significant differences in national approaches to the governance of aviation security and the economic consequences of such decisions.

1. Introduction

A fundamental problem underlies the provision of aviation security; how to best allocate scarce resources in order to reduce the probability of a successful attack against civil aviation to an acceptable level. The economic concept of scarcity has two important meanings here. Firstly, resources devoted to defense activities of any kind (including aviation security) do not directly increase economic welfare (rather such activities serve to prevent potential reductions in welfare). When we are forced to expend resources to protect ourselves we are reducing the resources available for investment in capital goods and technology and for production and consumption of goods and services. Secondly, given a finite budget allocated to the general activity of national defense, the resources devoted to aviation security represent a reduction in resources available to protect non-aviation targets. Moreover, the resource allocation problem is complicated by the fact that such decisions are strategic; aviation security risks are not the same as natural disaster risks. For example, if we decide to allocate more resources to ensure buildings are earthquake-proof, this does not change the probability of an earthquake occurring. However, if we allocate relatively more resources to one aviation security measure (and relatively less to another) we change the expected payoffs to terrorists and thus potentially change the probabilities and modes of attack.

This article provides an overview of current issues and future prospects for aviation security from an economic perspective and introduces the other articles in this special issue. We begin with some background on aviation security over the last four decades. In Section 2, we present some data on the costs of aviation security in Canada and the US and some analysis of the costs of aviation security at European airports, noting sizable differences across airports even in the same country.[1] In Section 3, we discuss difficulties in defining and measuring output and the use of benefit-cost analysis to aid in resource allocation. We also outline input relationships in the production of aviation security layers and the role of human factors in the delivery and efficiency of aviation security. Section 4 examines the financing of aviation security and the relationship between financing and governance. In Section 5 we discuss the potential evolution of international security towards a risk-based system and we offer some brief concluding remarks in Section 6.

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[1] Much of the data we report focuses on the USA and Canada for the simple reason that data for other jurisdictions are not consistently available in any form that permits analysis or comparison. In most cases there needs to be a dramatic improvement in the collection, transparency, consistency and reporting of data related to aviation security.

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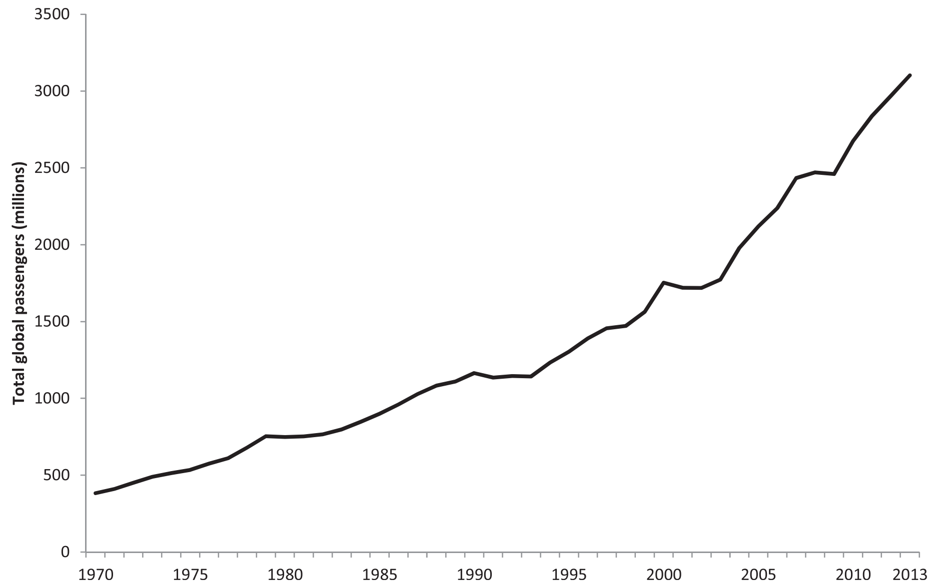

Fig. 1. Total global air passengers (millions); 1970–2013.
Source: Airlines for America [2]

1.1. Background

In the last 45 years, trade, technology, and economic growth have created an age of globalization in which the welfare of people, firms and nations have become ever more interconnected. During this period, civil aviation has evolved from a heavily regulated system of national airlines and government operated airports to a much larger and more competitive global industry in which private airlines and airports compete along with publicly owned counterparts and hybrid organizations under diverse regulatory regimes. Fig. 1 shows the remarkable growth in the number of global air passengers over the last 43 years, a long-term trend which has been largely impervious to the negative shocks of macroeconomic recessions, health crises, military conflicts and acts of terror. In 2013, approximately 3.1 billion air passengers were transported.

However, civil aviation has been a visible target for acts of violence and terrorism throughout this period. Fig. 2 shows the total number of attacks inside planes worldwide by attack type over the four decades between 1970 and 2009 and indicates the percentage of total attacks in each decade accounted for by each attack type.

In the 1970's, attacks on aircraft were heavily skewed towards hijackings however this mode of attack has declined both in number and in relative importance over time. The figure also shows a sharp rise in the number of bomb attacks that occurred in the 1980's falling again in the subsequent decades. The data thus captures the evolutionary nature of aviation security; as authorities implement security measures to nullify a given mode of attack, terrorists adapt their strategies and the preferred mode of attack evolves. Overall the total number of attacks has declined significantly over time with 111 attacks in the 1970's but just 21 attacks between 2000 and 2009. In terms of fatalities, there were a total of 557 deaths as a result of all attacks inside planes in the 1970's. This number rose to 1115 in the 1980's mainly as a result of a small number of attacks that inflicted a large number of casualties, including Air India flight 182 in 1985 (329 fatalities) and Pan Am flight 103 in 1988 (270 fatalities). In the 1980's the objectives for attacking aircraft had evolved from attention-seeking through prolonged live media coverage of a hijacking to the shock and terror generated by the sudden and unexpected mass killing of innocent civilians. By the 1990's aviation security had responded and was evolving into a complex (and expensive) system combining intelligence agencies, security personnel at airports and investments in scanning equipment to detect bombs, weapons and prohibited items. In the 1990's, the total number of fatalities from all terror attacks inside planes declined to 160, but the following decade will forever be defined by the 2938 deaths resulting from the attacks in New York and Washington on September 11th, 2001. Excluding the 9–11 attacks, there were just 94 fatalities worldwide as a result of terrorist attacks inside aircraft from 2000 to 2009.

The events of September 11th, 2001 represent by far the biggest and most shocking realization to date of the ever-evolving threat of terror attacks against aviation. In particular, the attacks demonstrated how civilian aircraft could be used as weapons to kill large numbers of civilians and destroy assets on the ground. The attack created mass panic over the vulnerabilities of the civil aviation system and led to sweeping and significant changes in the design, provision and financing of aviation security throughout the world. Since 2001, governments have created new organizations to implement airport security systems and there have been massive investments in both technology and the hiring and training of security personnel. Through all of these changes and increases in security costs, airports and airlines have faced new challenges in managing passenger throughput, minimizing delays and negative passenger experiences resulting from elevated levels of security effort. The general public and the travelling public have borne both the direct and indirect economic costs of these investments.

2. Costs of aviation security

Unless significant changes are made, the monetary and economic costs of the current aviation security system are likely to

[2] Airlines for America (2015); data from http://airlines.org/data/annual-results-world-airlines.

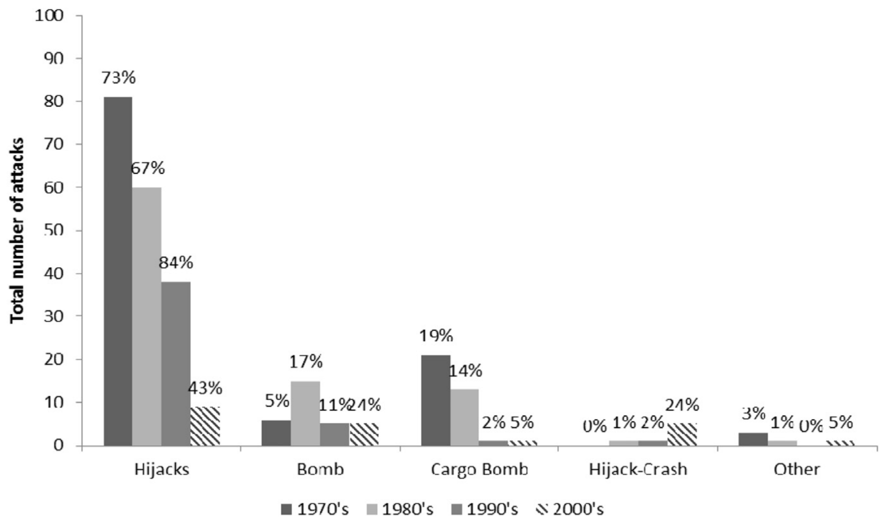

Fig. 2. Total worldwide attacks inside aircraft by type of attack; 1970–2009.
Source: Rand Database of Worldwide Terror Incidents.

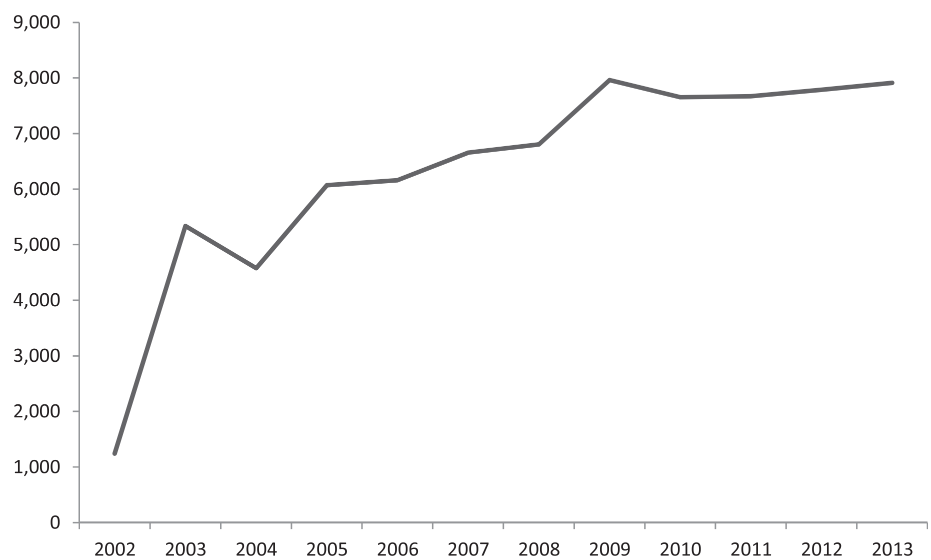

Fig. 3. : Transportation security administration total expenditures; 2002–2013 ($US millions).
Source: Published budgets of the Department of Homeland Security (2002–2012);[6].

reach unsustainable levels over the next 15–20 years as the number of air travellers and air cargo continue to grow. The number of air passengers is predicted to grow at an average annual rate of between 4.2 and 4.7 percent through to 2033 and approximately 85% of this growth is predicted to occur on our current (2014) aviation network, By 2030, approximately six billion passengers annually will require security and screening at airports around the world.[3]

A study requisitioned by the European Commission estimates that in 2002, European total expenditures on aviation security (for 18 member states) totalled €2.8 billion ($2.7 billion US).[4] We estimate that total spending on aviation security by European airports has more than doubled in under 10 years, reaching €5.7 billion ($7.6 billion US) in 2011.[5] A more complete picture of the trend in aviation security expenditures is available for the U.S. and Canada. Fig. 3 shows U.S. government funding of the Transportation Security Agency (TSA) has increased significantly since its inception, growing from $2.2 billion in 2002 to almost $8 billion in 2013.

Fig. 4 shows the trend of expenditures in Canada over the same period, where spending by the Canadian Air Transport Security Authority (CATSA) increased in much the same pattern but peaking

[3] See for example, The Boeing Company (2014) and Airbus (2014, 2011).
[4] Irish Airports Authority/Avia Solutions (2004), p113.

[5] We use data on operating expenses for 75 European airports in 2011 (ATRS airport benchmarking data) and an estimate of average aviation security costs at 20% of total airport operating costs in 2012, as reported by Airports Council International; https://www.aci-europe.org/policy/fast-facts.html.
[6] See U.S. Department of Homeland Security (2002–2014).

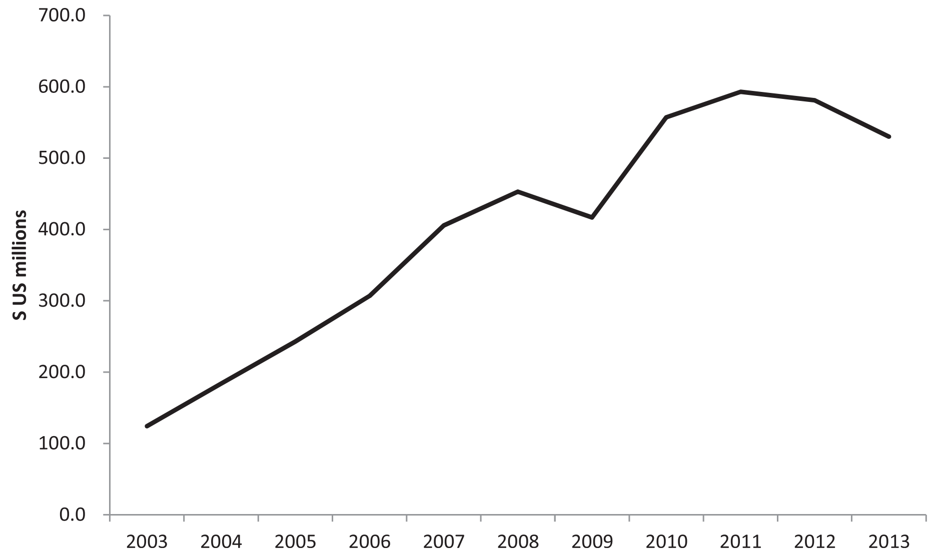

Fig. 4. Total CATSA (Canada) expenditures ($US); 2002–2013.
Source: CATSA annual reports (2003–2014); Bank of Canada.

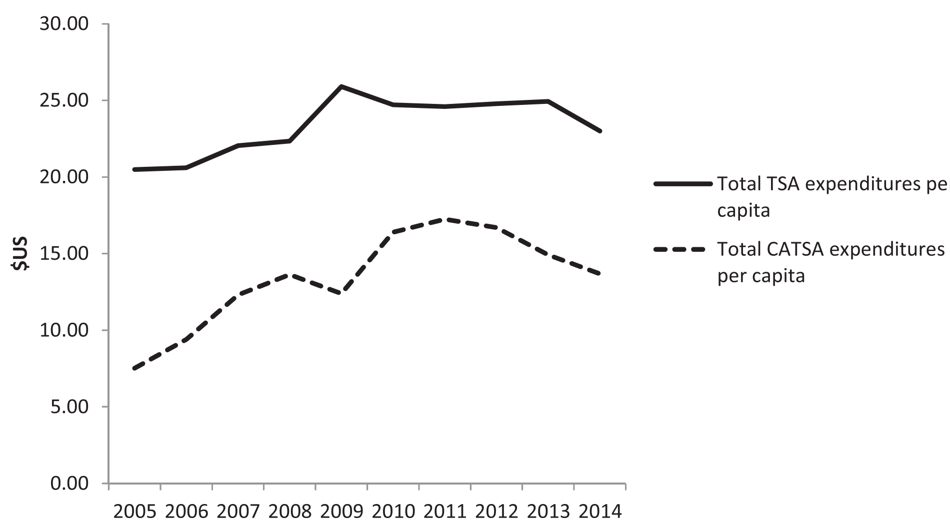

Fig. 5. Comparing TSA and CATSA total expenditures per capita ($US); 2005–2014.
Sources: US Census; Statistics Canada; Department of Homeland Security; CATSA.

at $600 million US in 2011 and declining thereafter. The relative size of the U.S. and Canada make comparisons of absolute spending unenlightening, consequently, Figs. 5 and 6 show spending on aviation security per capita and per screened passenger in the two countries from 2005 to 2014. Fig. 5 reveals a significant difference between the two countries in terms of spending per capita, with the U.S. spending on average $9.92US more per capita that Canada over the ten-year period.

Fig. 6 also shows the U.S. spending more than Canada per screened passenger although the difference is much smaller, driven by the fact that the number of air passengers in the U.S. (relative to the population) is much larger than in Canada. The mirrored spike in expenditures for 2009 reflects different responses to the financial crisis and recession in the two countries. While passenger volumes declined in both Canada and the US (reducing revenues from aviation security charges), spending per screened passenger rose in the U.S. but declined in Canada. Part of the explanation lies in differences in how aviation security is financed in the two countries. We discuss this further in Section 4.

Although there is limited country level data available, we have attempted to analyze how costs change with changes in the total number of passengers served (aggregate at the country level). We investigate two costs; (a) total operating plus capital costs and (b) passenger screening and bag check costs. The former employs data from Canada, U.S. and Australia and the latter uses data from Canada, U.S. and New Zealand. All costs are in real terms and expressed in Canadian dollars.

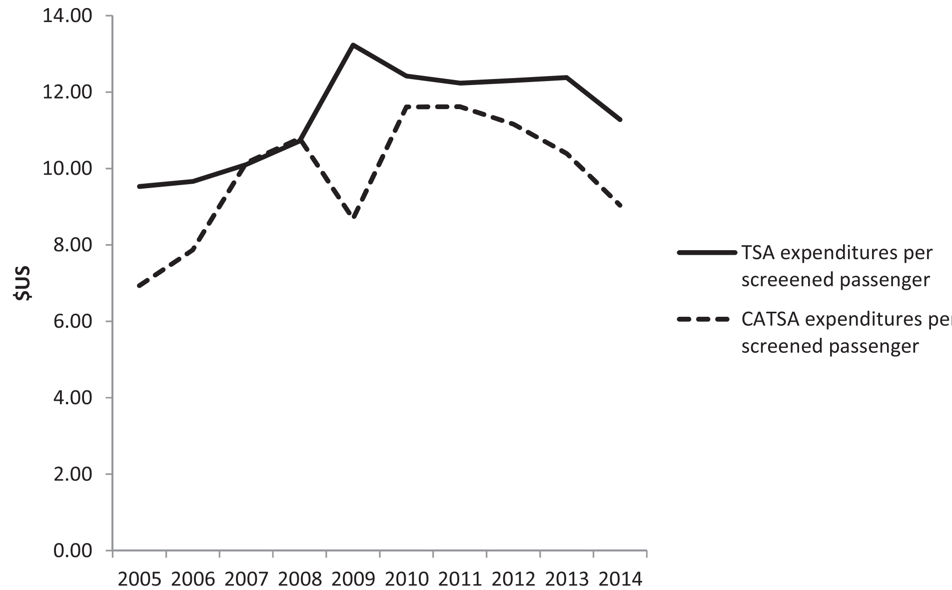

Fig. 6. TSA and CATSA total expenditures per screened passenger[7]; ($US); 2005–2014.
Sources: Department of Homeland Security, TSA Blog: Year in Review, Federal Aviation Administration, CATSA.

Table 1
Regression of total operating plus capital expenses by country.

Dep Variable:	Total cost (operating &capital expenses)	
Observations: 30		
	Linear	
	Coeff.	t-stat
Intercept	−977746.53	−2.26
US	−2550111.73	−0.46
Australia	−338973.79	−0.87
Passengers	11.79	1.44
Time	167301.43	3.06
R SQ	0.96	
F-statistic	90.81	

Table 2
Regression of passenger screening & boarding costs by country.

Dep. Variable:	Passenger boarding and screening costs	
Observations: 30		
	Linear	
	Coeff.	t-stat
Intercept	−780375.0384	−3.79
US	−2269669.527	−0.86
New Zealand	71298.54	0.38
Passengers	9.56	2.46
Time	73758.85	2.84
R SQ	0.98	
F-statistic	216.53	

Table 1 reports regression results for total operating and capital expenses, with total cost as the dependent variable.[8] Neither country dummy variable is significant, meaning there is no difference in costs between Canada, U.S. and Australia that would be explained by some other variables or that are inherent to those respective countries. The incremental cost of serving a passenger is $11.79 and costs have been increasing over time as indicated by the positive and significant coefficient on the time variable.[9] Evaluating the elasticity of total cost with respect to changes in the number of screened passengers at the mean, gives an elasticity of 0.96 which implies very slight cost economies.

In Table 2, the same variables as used in the regressions reported in Table 1 were regressed on total passenger screening and baggage costs. Three countries were included in the data set – Canada, U.S. and New Zealand. In Table 2, neither of the country dummy variables are significant, while passenger-screening costs in real terms are increasing over time. The incremental cost of serving a passenger is $9.56 (CAN). Evaluating the elasticity of passenger and screening costs at the mean yields a value of 0.536; a 1 percent increase in screened passengers increases boarding and screening costs by 0.536 percent. This value indicates significant cost economies, which is reasonable given that a fixed team of screeners can process an increasing number of passengers before having to add another screening team.

Europe has a different model to fund and provide aviation security whereby National governments set security standards and each airport in a country (or member state) provides the security services (either through producing it themselves or contracting out) and levies a charge on airlines and/or passengers.[10] Although data is limited, we were able to construct measures of security costs for a sample of airports. In Fig. 7 average security cost per passenger varies from $6.28 at Saltsburg Airport, Austria to $0.73 at Sabiha Gokcen Airport in Istanbul. The average cost for all airports in the sample was $2.88 per passenger. These numbers will be somewhat distorted if transfer passengers are not screened when they connect and there will be some expenses for screening cargo and to the extent an airport handles a significant amount of cargo, this will upward bias the averages. To correct for these possible biases we

[7] For the US, the number of screened passengers is estimated from enplanement data for all years except 2013 and 2014. In 2013, 2014 TSA published the total number of screened passengers in their 'year in review'. We estimate the number of screened passengers by applying the ratio of screened passengers to total enplanements in 2013 to total enplanement data for all the other years.

[8] This model was estimated using both linear and log–log specifications. The linear model was superiod in fit.

[9] Time could have also been specified as a dummy for each year. However, there were too few observations to allow for this.

[10] Aviation Security in the European Union is set out in EC Regulation No. 300/2008) which came into fll effect April 29, 2010.

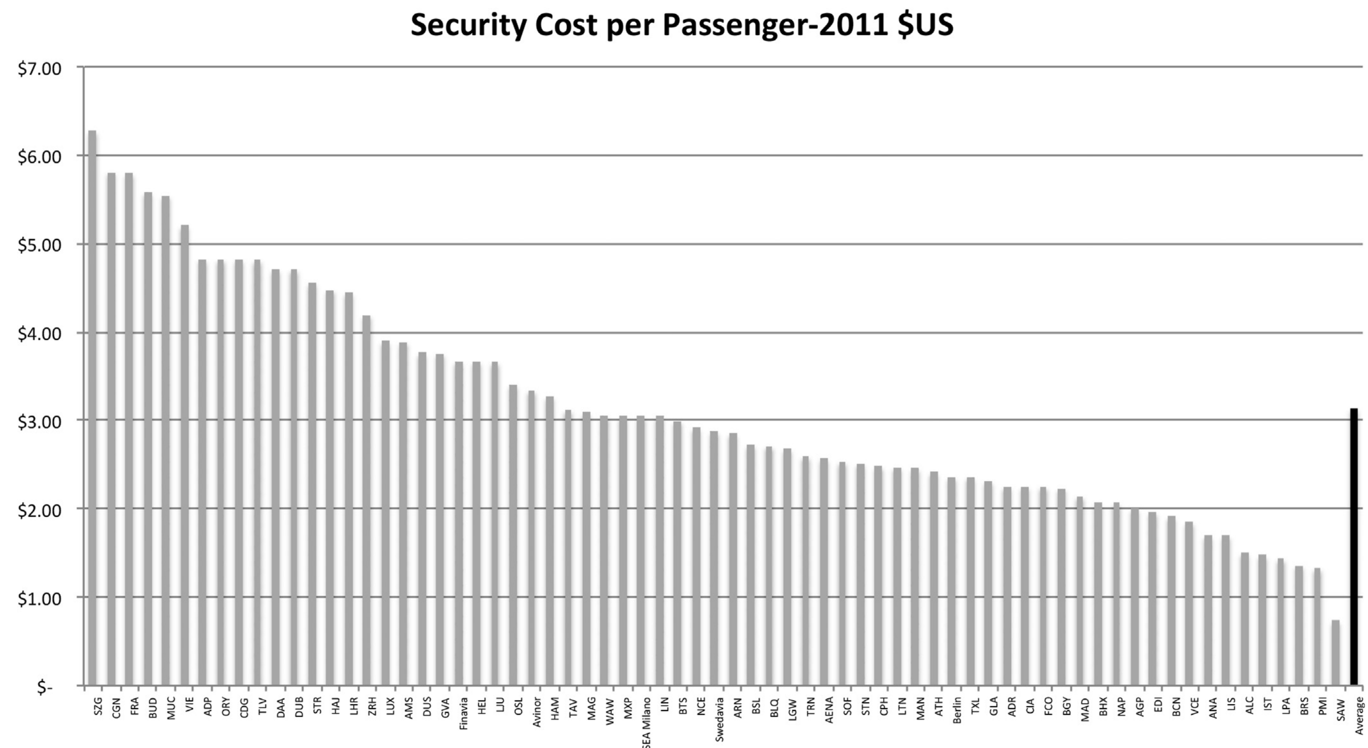

Fig. 7. Security cost per passenger; European airports; 2011 ($US).
Source: ATRS airport benchmarking data (2011); author's calculations.

Table 3
Regression of total security cost for sample of EU airports.

Dependent Variable: Total security cost sample: (Adjusted) 1, 57				
	Linear		Log-linear	
Variable	Coefficient	t-Statistic	Coefficient	t-Statistic
Constant	2582748	0.11	1.055	1.17
Passengers	**2.59**	6.60	**0.940**	14.92
Gateway dummy	11805108	0.49	−0.254	−0.98
Large hub dummy	**46353938**	2.34	**0.468**	2.00
Percent international	3270769	0.15	0.106	0.57
Cargo	**36.33**	3.29	**0.094**	2.96
UK	−3108878	−0.19	−0.101	−0.50
Germany	782348	0.48	0.233	1.07
Netherlands	**−54988685**	−2.04	−0.191	−0.57
France	−4100851	−0.22	−0.012	−0.05
Spain	**−35316021**	−2.00	**−0.463**	−2.19
Portugal	−22496096	−0.91	**−0.611**	−1.95
Turkey	**−57742523**	−2.48	**−1.060**	−3.52
Norway	−37106233	−1.19	−0.303	−0.76
Austria	19758673	0.97	**0.606**	2.35
Switzerland	−2920647	−0.13	0.149	0.54
Italy	−9090521	−0.55	−0.123	−0.57
Sweden	−5395703	−0.21	−0.092	−0.29
Finland	4548366	0.18	0.121	0.38
Denmark	−20143385	−0.80	−0.317	−0.99
Hungry	5234784	0.26	0.202	0.79
Greece	−10445515	−0.41	−0.213	−0.67
Poland	−4349492	−0.21	−0.004	−0.01
Adjusted R^2	0.95		0.96	
Log likelihood	−1025.32		13.09	
F-statistic	31.11		42.28	

estimated a cost model that included cargo, percentage of international passengers, whether the airport was a large hub and/or gateway and dummy variables were used to examine differences across countries. The results are reported in Table 3. The regression estimated is specified as:

Security Cost = g(passengers (#), cargo (tonnes), percent international passengers, Large Hub Dummy, Gateway Dummy, Country Dummies (UK, Germany, Netherlands, France, Spain, Portugal, Turkey, Norway, Austria, Switzerland, Italy, Sweden, Finland, Denmark, Hungry, Greece and Poland).

Table 3 presents the results of two regression specifications (linear and logarithmic) with statistically significant coefficients indicated in bold. The results of the two specifications are quite similar. The marginal cost per passenger is $2.59; substantially less than the previous regression that included data for U.S., Canada and Australia. However, the elasticity of cost with respect to passengers is estimated to be 0.94, a similar figure to what was estimated earlier. Security costs are higher for large hubs and not surprisingly, cargo adds $36.33 per tonne to security costs, with an elasticity of 0.09.[11] The proportion of international passengers does not seem to affect overall security costs in the EU. This is somewhat surprising given the large connecting hubs of Frankfurt, Munich, Charles de Gaulle, Amsterdam (Schiphol) and London Heathrow. However, all traffic between Schengen member states is considered domestic traffic. Spain, Portugal and Turkey have lower security costs on average and Austria has higher costs, otherwise there are no significant cost differences among EU member states.

2.1. Air cargo

Air cargo includes hold-checked baggage of passengers travelling on a flight, belly hold air freight travelling on a passenger aircraft and freight travelling on dedicated air freighter aircraft.

[11] A 1 percent increase in cargo tonnes leads to a 0.09 percent increase in costs.

Each of these types of 'cargo' are treated differently for security screening.

Checked luggage is passed through machines that can detect certain materials, liquids, explosives and identify objects that could be a threat. In the early 2000s when there were not enough machines to screen checked baggage there was a positive bag match program put in place. This required that any bag on a flight had to match with a corresponding passenger on that flight. This program has evolved such that a passenger cannot have control of their checked luggage. All checked luggage is screened but may be placed on an earlier or later flight, the passenger whose bag it is, does not know this. On long haul flights for all intents and purposes, checked baggage and passengers match.

There is a large dedicated air freighter fleet; air freighters move 72% of airfreight from SE Asia to Europe and carry 80% of transpacific and 43% of trans-Atlantic air freight.[12] Screening of air freight in some respects is easier than screening passengers, with less stochastic demand and 100 percent use of technology. However, implementing the screening cargo in belly hold of aircraft has taken longer than passenger screening. There are a number of difficulties. For example, it is not feasible to screen air freight at the last minute to put on an aircraft since it is in containers or palletized. The amount and range of screening equipment varies across airports and some cargo is too large for x-ray equipment. A second, and serious problem is the varying standards for inspecting air freight inbound from other countries. This was brought to the fore in 2012 when terrorists attempted to ship printer tonner cartridges from Yemen to the U.S. containing explosives.

ICAO has created a set of standards, including screening (where practicable) for all air freight prior to flight departure.[13] A key component of the program is to have regulated inspectors inspect air freight and maintaining it in secure premises prior to being shipped; this is part of the Air Cargo Advance Screening Programme developed by U.S. Department of Homeland Security. While this program relies on x-ray and screener inspection for air freight in belly hold, for larger air freight it relies on significant amounts of advance information concerning the items being shipped including consignor-shipper, origin freight forwarder, ground handler, carrier, destination ground handler, destination freight forwarder and consignee. This approach is a risk based method where more detailed inspection are carried out on high risk freight/cargo.

In the EU all carriers carrying cargo into the EU from a 3rd country must apply for an 'Air Cargo or Mail Carrier Certificate' (ACC3). Independent validators for inspecting air freight were to be trained and positioned in non-EU countries. A program was also initiated for air cargo advanced screening. Firms would be registered and have an 'authorized economic operator' to carry out security inspections. This program is similar to the U.S. program, Customs-Trade Partnership Against Terrorism (C-TPAT). The later program relies on careful and thorough data/information analysis on air cargo shipments.

3. Defining and measuring output in aviation security

Production theory can be utilized to position our thinking about trade-offs between various inputs in the production of aviation security services.[14] In economics, a production function describes the technology of production by relating how various inputs (e.g. labor and capital equipment) are combined to produce a definable output. This approach highlights the fact that within a given technology of production, the same level of output can be produced using different combinations of inputs. For example, a given level of aviation security might be obtained in either a labor intensive or a capital intensive way or via some balanced combination. The optimal (most efficient) means of production will depend upon the relative productivity and cost of each input.

In practice, while measuring inputs and costs are possible, defining and measuring output is challenging. The output of aviation security is hard to measure because the intended outcome of all security activities is the mitigation of threats, so what exactly is produced? Ideally we want to measure the total costs (loss of human life, destruction of assets etc.) that would have occurred had a particular security measure or series of security measures not been in place, but this is not observed. Without a clearly specified measure of output, one cannot easily perform benefit-cost analysis, which is required if we are to efficiently allocate resources between aviation security and other potential activities or if we wish to allocate resources efficiently between competing security measures. Consider a project, which requires some initial investment of funds in year 0 and continued funding each year for the life of the project until the project ends in year T. The project will yield a stream of economic benefits and costs given by:

$$V = \sum_{t=0}^{T} \frac{B_t - C_t}{(1+r)^t} \tag{1}$$

where B_t and C_t are the benefits and costs realized in period t and r is the rate of interest (discount rate) in a competitive capital market. Applying the logic of benefit-cost analysis to aviation security, for a given security measure we want to re-interpret B_t as:

$$B_t = \left(p_{t,-s} - p_{t,s}\right)k_t \tag{2}$$

In (2) $p_{t,-s}$ represents the probability of attacks in year t without the implementation of the security measure and $p_{t,s}$ represents the (reduced) probability of attacks in year t after the implementation of the security measure. Variable k represents the value of lives and assets expected to be destroyed in successful attacks annually. As already stated, these probabilities can only be conjectured from historical evidence and intelligence. Nevertheless in spite of these difficulties, it is possible for benefit-cost analysis to generate insights in support of improved resource allocation decisions, providing we are able to make certain informed assumptions about the risk reductions associated with any given security measure. Stewart and Mueller (2008) use such an approach to assess specific aviation security measures in the U.S. in the aftermath of the September 11th attacks. A key element in their approach is the use of sensitivity analysis to provide the ranges of probabilities required for a given security measure to generate net benefits. This step is essential as a robustness check on the reliability of the estimates. In the first article in this special issue, Christopher Stewart and John Mueller extend their research to evaluate the PreCheck (trusted traveller) program in the US. Their analysis calculates the benefits of the current US aviation security system with and without the PreCheck program. They show that under very conservative assumptions (concerning the ability of a trusted traveler system to detect terrorists and the overall probability that any citizen is a terrorist) that the net effect of the PreCheck program is to generate benefits and efficiencies while likely improving the overall level of security.

[12] See Boeing Air freight Forecast 2014–2015.
[13] See, ICAO, Moving Cargo Globally: Air cargo and Mail Secure Supply Chain, 2013.
[14] See Coughlin et al. (2002), p22.

3.1. Productive efficiency and input relationships

Productive efficiency (measured by the cost of producing a given level of output, holding quality fixed) can vary depending on how labor effort is combined with various capital inputs. In the realm of aviation security, the ways that capital assets embodying new technology interact with human labor effort have very real and important implications for the overall level of security provided and for efficiency. In the second article in this issue, Paul Benda brings his years of experience in the U.S. Department of Homeland Security to bear on issues relating to the current and future role of technology in aviation security. In his commentary article, Mr. Benda argues that technology has the potential to not only improve the level of security but also to improve efficiency and provide passengers with a better air travel experience. He emphasizes the importance of upgradeable technologies and suggests that in future, technology will enable more centralization and consequently can increase the productivity of airport screening, which implies changes to way security personnel are currently employed.

To take advantage of technology improvements, the institutions governing the provision of aviation security need to be flexible enough to not only adopt new technologies but to make necessary changes in the mix of inputs. New technologies (biometrics for example) offer the potential to change the way that aviation security is provided, however the adoption of such technologies is also problematic because of the limitations in our ability to measure output. To the extent that the adoption of a new technology implies a different set or combination of inputs than was used in the past, policy-makers and those overseeing the security system face a difficult task in assessing the impact. In the absence of counterfactual evidence, a new technology could be blamed (rightly or wrongly) for creating vulnerabilities (if a successful attack were to occur after its implementation, for example), especially if the new technology replaces elements of the old system. Such measurement problems create an institutional incentive to only make changes that add additional layers to the system without reductions in existing measures. The danger then is that over time, more and more layers are added without any corresponding reallocation of resources. Not only will this increase costs over time, but it may also create inefficiencies and suppress the intended benefits of new technologies.

Our third article in this issue by Brian Jackson and Tom LaTourette provides an analytical structure for understanding how different layers of aviation security interact. Jackson and LaTourette demonstrate how each layer of security can be mapped onto four general attacker paths. In their analysis, Jackson and LaTourette introduce the possibility that a new layer of security could place resource demands on existing layers that lead to reduced or compromised effectiveness. Importantly, Jackson and LaTourette assume 'intelligent adversaries' who adapt in response to new security measures. This approach to evaluating layered security lays open the possibility of more detailed cost-benefit analysis of security measures and provides a framework to facilitate the possible removal or scaling down of existing security layers as new layers and technologies are adopted. This is an essential step if aviation security costs are to be kept under control as the system evolves.

The traditional neoclassical production function in economics is silent on matters pertaining to organizational structure and human behavior; and yet these factors can be critical in aviation security. Assessing security risks through the screening of passengers involves human interaction and communication not only between passengers and screening agents, but also between the various groups involved in the overall security process. In our fourth article, Alan Kirschenbaum presents a view of airports as complex service organizations with a mix of formal and informal organizational structures and information flows. In particular he highlights the importance of social networks and the evolution of informal communication channels and decision-making processes. Dr. Kirschenbaum's study of European airports provides data on how security and screening decisions are actually made and the flow of information around those decisions. The results indicate that security personnel do not behave the way they might be expected to in a theoretical representation of their organization and its formal processes. Furthermore his study suggests that in contrast to the traditional view of passengers as "passive cogs" in security process, passengers interact with screening personnel and this has important implications for screening time.

The fifth paper in this issue also explores human factors in the area of passenger baggage screening. In an operations-focused approach Jacek Skorupski develops a model and a computer system capable of taking human factors into account in the screening process. His model incorporates subjective dependencies into the decision-making process by employing a fuzzy inference system with parameters based on a combination of expert opinion and field research at Katowice-Pyrzowice airport. Dr. Skorupski argues that such modelling can be used to evaluate security screening agents and to improve the structure of training programs to optimize performance and improve efficiency.

4. Aviation security financing

The financing of aviation security post-2001 has not happened in a uniform way around the world and in particular is tied to a variety of different nation-specific governance structures. Unfortunately there is little to no transparency concerning exactly how much national governments are spending on aviation security from general tax revenues and how much air travellers and airlines are paying for aviation security through earmarked taxes and charges. While some data on delineated security charges is available for some countries (Germany, Italy, Spain for example), there is no way to ascertain if these published charges represent total financing. In countries with government run airports (China for example) government financing likely exceeds revenues from published security taxes, which are set relatively low. Meanwhile in countries with privately owned airports (the UK and Australia for example) individual airports do not publish delineated aviation security charges levied on airlines and passengers but instead publish 'passenger service charges' which encompass a number of different services, one of which is aviation security. In these cases it is also unclear how much (if any) government expenditures cross-subsidize some aspects of aviation security. For this reason, below we only report data from Canada and the U.S. where more accurate data is available. However this two-country comparison is sufficient to demonstrate two very different approaches to the financing of aviation security.

The governments of the U.S. and Canada both reacted very quickly to the September 11th attacks but in different ways. The U.S. elected for a model in which one large federal government department (the TSA) would take over all aspects of aviation security including oversight of security standards at airports, testing and adoption of new security technologies and the training and provision of screening personnel across America's airports. Correspondingly, a large proportion of the costs of aviation security in the U.S. have been financed out of general tax revenues with the remainder provided via revenues from a security tax levied on air travellers. In 2001, the government introduced the September 11th security fee, which was set at $2.50 per enplanement per passenger per one-way trip, up to a maximum of $5. There was also an aviation security infrastructure fee which is a fee levied on air carriers equal to the cost for passenger and baggage screening in the year

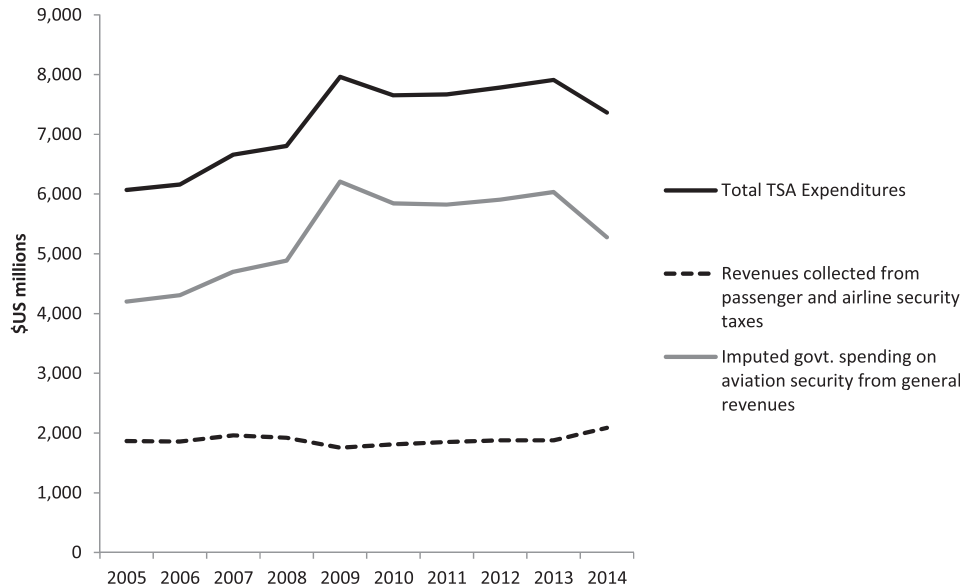

Fig. 8. TSA total expenditures, revenues from security charges and imputed government spending on aviation security; 2005–2014.

2000; these were estimated by GAO to be between $450 and $471 Million.

In Canada, the model was different. The federal government created the Canadian Air Transport Security Authority (CASA) as an independent agency with a mandate to test and implement new security technologies and to oversee the training and standards of security personnel. Unlike the U.S., under the Canadian model, security personnel are supplied by private market firms. The Canadian government instituted its own federal tax on air passengers; the 'air travellers' security charge' (ATSC) however in contrast to the U.S., the tax was intended to cover all of CATSA's expenditures (with no additional spending coming from general tax revenues). Thus the relative financial burden facing air passengers versus all citizens in Canada is very different than in the U.S.

Fig. 8 shows a breakdown of total expenditures for the period 2005–2014 by the TSA. One can see that the revenues collected via the September 11th security fee has remained relatively flat over the period. Given an increase in spending following the financial crisis and recession in 2008, government spending increased accordingly. One can see a decline in total and government spending in 2014 and a slight rise in the revenues collected from the security fee. In 2014, the U.S. government increased the September 11th charge to a flat fee of $5.60 (regardless of the number of enplanements) per one-way-trip. Furthermore, in the proposed 2014 budget by the Obama Administration, the plan is to increase the September 11th security fee by approximately 50 cents each year until 2019.[15] Thus while the U.S. has opted for a blend of user-pay and citizens-pay in the financing of aviation security, the blend is changing with relatively more burden in the foreseeable future being placed on air travellers.

Fig. 9 displays a similar breakdown for Canada over the same period. While the figure only shows data from 2005 to 2014, total revenues from the ATSC exceeded CATSA expenditures both prior to 2007 and after 2011. Part of the explanation derives from capital spending which began to increase steadily in 2004 so that by 2007, total spending was greater than total revenues from the ATSC. The effects of the financial crisis and recession, dampened ATSC revenues in the face of these higher capital costs and this led the federal government to increase the ATSC in 2010. These rate increases were significant, with the domestic fee per chargeable enplanement doubling from $4.67 CAN (maximum charge of $9.33) to $7.12 CAN (maximum charge of $14.25). The ATSC for transborder passengers increased from $7.94 CAN per chargeable enplanement (maximum charge of $15.89) to $12.10 CAN (maximum charge of $24.21). Finally, the ATSC for international passengers increased from $17 CAN to $25.91 CAN. These increases in ATSC rates combined with the slow but steady recovery of the macro economy and air passenger traffic has caused ATSC revenues to increase dramatically in the last few years, while capital spending and variable costs have declined.

Thus the current trend shows growing annual surpluses, which simply revert to become general revenues for the federal government.

Using 2011 data, Gillen and Morrison (2015), estimate the welfare loss in Canada due to the imposition of security fees for that year.[16] According to these estimates, in 2011 there were 690,000 fewer passengers flying to/from and within Canada as a result of the air transport security charge. This translates into $227 Million in forgone revenue to the airlines and an economic welfare loss of $2.2 Billion.[17]

Fig. 10 illustrates the significant differences in revenue per passenger from security fees. Per passenger revenue for Canada is climbing at an alarming rate while for other countries revenue per passenger is leveling off. The U.S. collects the lowest amount and despite recent increases in passenger security charges there, remains well below other countries.

The issue of who should pay for aviation security is a fundamental economic question and one that rests to a large extent on who we think benefits from aviation security. In the sixth article in this special issue, Barry Prentice reviews the economic arguments for and against a 'user pay' versus an 'everyone pays' approach. He argues that many of the benefits of airport security accrue to the

[15] See House of Representatives Committee on the Budget (2013).

[16] See, David Gillen and William Morrison (2015), Issue in Aviation Security (paper presented at the Canadian Economics Association Meeting, Toronto).

[17] This does not include other relevant indirect losses to passengers and airlines from delays, inconvenience and declines in economic activity.

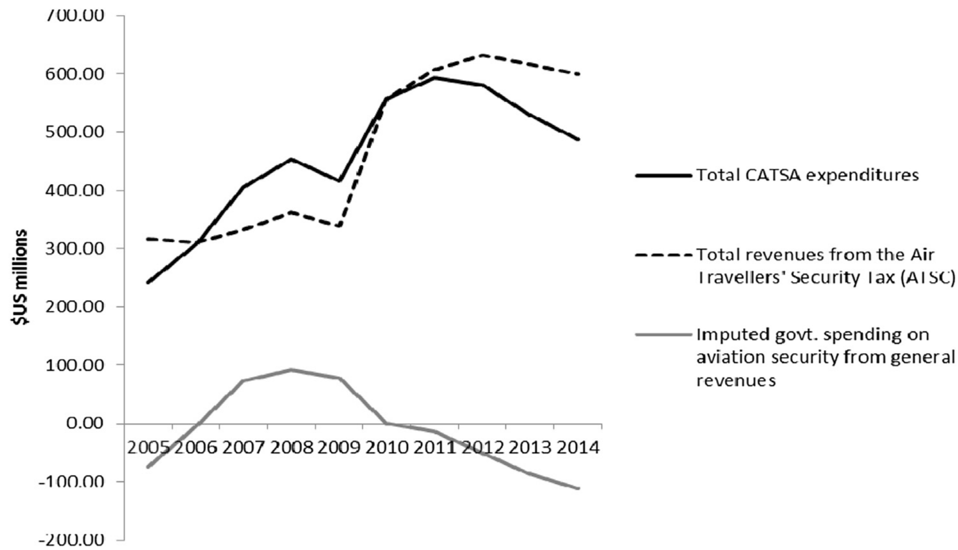

Fig. 9. CATSA total expenditures, revenues from security charges and imputed government spending on aviation security ($US); 2005–2014.

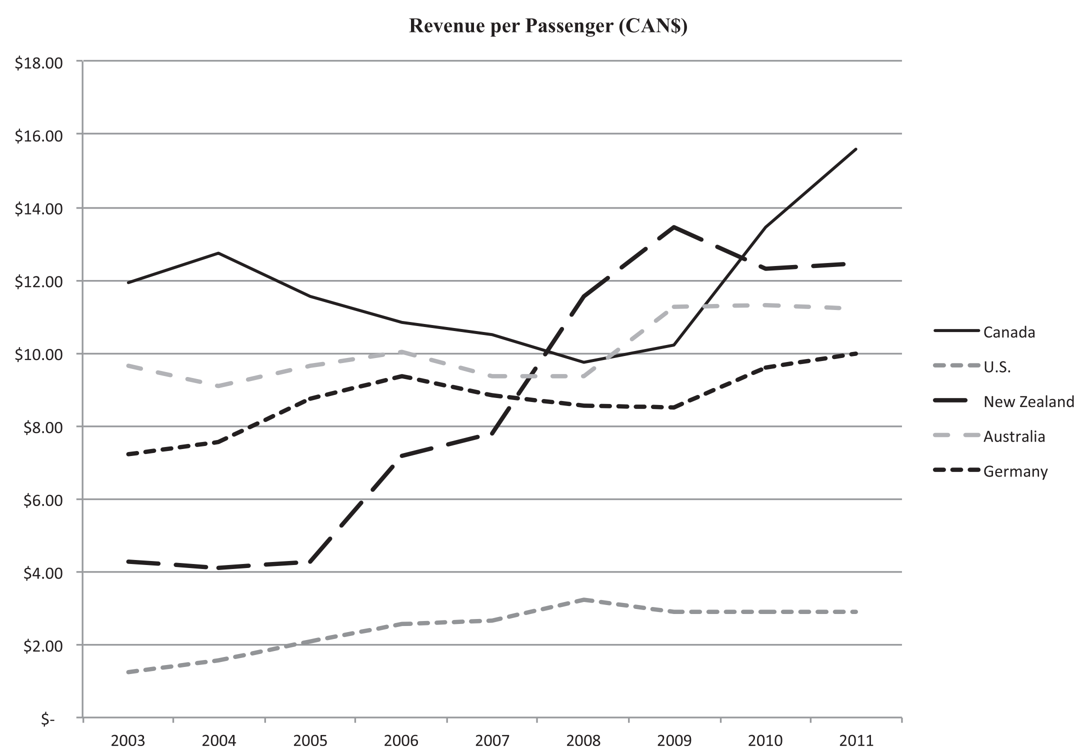

Fig. 10. Revenue per passenger from security fees; international comparison.

general public and as such aviation security is a ‘public good’, similar to national defense. Dr. Prentice's assessment of the Canada's ‘user pay’ approach is that it is discriminatory, distortionary and ultimately self-defeating.

5. The evolution to risk-based aviation security

Until very recently, the aviation security system has operated on the assumption that each and every passenger at an airport is a potential terrorist until shown to be otherwise. Under this approach, all passengers receive the same degree of screening and attention as they pass through security checkpoints. The result has been the line-ups and delays that are now a reality of air travel. In recent years however, there has been growing support for adopting risk-based aviation security measures, including the creation of trusted traveller programs. In a risk-based security system, passengers are divided into risk categories with a potentially large segment of the travelling public classified as low-risk, thereby requiring less evasive and less time-consuming screening at the airport. The institutions and technology supporting this approach consist of the following main elements:

- Trusted traveller programs: Passengers submit to a pre-screening process that assesses their risk level. Qualified individuals are then eligible for expedited screening procedures at the airport.

- Random checks: The lowest risk passengers will still be subject to random selection for more intense screening at the airport
- Biometrics: Biometric identification technology can be utilized to help ensure that individuals cannot steal or procure the identity of low-risk trusted travellers.
- Real time behavior assessment: Trained agents at an airport select passengers for more intense screening if their behavior or answers to interview questions raise suspicions concerning their risk level.
- Real time intelligence and information: Intelligence authorities with information on changes in a person's risk-status convey that information in a timely manner to security personnel at the airport.

The combined effects of these elements offers the possibility of maintaining or enhancing security levels while reducing wait times and delays for passengers, however there are many questions to be answered. How much will a risk-based system cost relative to the current system? Can a risk-based system be harmonized and implemented globally? How do we know that a risk-based system can deliver equivalent or greater security?

International industry associations (notably IATA and ACI) have been independently developing and promoting risk-based security for some years now.[18] However in 2014, IATA and ACI announced a memorandum of understanding to harmonize their work and to jointly promote ‘next generation’ aviation security, with a focus on “airline–airport interface, airport throughput capacity and efficiency”.[19]

Annexes to the agreement are now being finalized to focus on the following improvement areas:

- Passenger flow at border crossings based on the Automated Border Crossing (ABC) project
- Passenger screening processes at targeted security checkpoints to maximize efficiency and productivity, as well as minimize passenger dissatisfaction
- Gaining support from airports and national regulators to build on the achievements of the Checkpoint of the Future project
- Airline – airport co-operation on Common Use Self Service (CUSS)
- Common technical specifications for data exchange standards at the airport
- Best practices in ground handling to drive improvements in safety, productivity and reduce overall risks
- Reducing mishandled bags and offering new products to passengers, including permanent bag tags and home-printed bag tags”[20]

The challenge is to engineer a coordinated international evolution to risk-based aviation security that preserves international standards. However such coordination can create prisoners' dilemma type incentives for each nation to delay implementation in order to wait and see the outcome of other countries’ adoption of risk-based measures. So far, there is a lack of data and analysis with which to measure outcomes, net benefits and net efficiency gains, but both IATA and ACI have begun the process of pilot studies.

In this issue, authors Solomon Wong and Nina Brooks offer an industry perspective on the need for risk-based security. They point to three key dimensions in the provision of aviation security at airports: time, staffing and physical space and argue that with the expected growth in air passengers, solutions must be found to improve the efficiency of airport security. By mapping the top ten origin-destination passenger flow locations in the world to geographic risk levels Wong and Brooks demonstrate that a one-size-fits-all approach to airport security cannot succeed and that risk-based approaches (along with technology) can allow airports to customize their security and to accomplish more with fewer resources.

On the same topic, Robert Poole offers an assessment of the U.S. experience to date with risk-based assessment approaches to aviation security. Mr. Poole outlines the evolution of risked-based assessment in the U.S. and argues that the current PreCheck program should implement 3rd party recruitment and should be expanded to baggage screening. Mr. Poole also argues that the current governance model in the U.S. is flawed because the Transportation Security Agency (TSA) is both the provider of aviation security and the regulator. Poole argues for a system similar to that employed in the UK, where individual airports are responsible for either providing or contracting out for security screening services. Poole also concludes that to date, behavioral screening programs in the US have not been successful.

6. Concluding remarks

In little over a century, our world has changed from a place where individuals traveled internationally without the need for a passport and with minimal to no security screening to one in which an ever-increasing amount of productive resources are allocated (away from other uses) to transportation security and aviation security in particular. Moreover, security screening amid the potential for acts of terrorism or other forms of violence against ordinary citizens has become part of our everyday lives. The research in this special issue makes a significant contribution to answering difficult questions that nonetheless must be asked. However many avenues for research remain and our hope is that this issue will spark new initiatives and discussions on this important topic.

Acknowledgments

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[18] IATA named its vision for aviation security “checkpoint of the future”, while ACI developed a concept it called “better security”.
[19] IATA (October 2013); https://www.iata.org/publications/ceo-brief/oct-2013/Pages/aci-iata-mou.aspx.
[20] Ibid.

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