Measuring the impact of waste management on health: the case of Campania.

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Outline of manuscript section headers:
Abstract, Background, Method, Results, Limitations of the study, Discussion

Abstract

Background Evaluating the economic benefit of reducing negative externalities resulting from waste management is of pivotal importance for estimating both the true social cost of current waste management practices and designing an effective solid waste policy that takes into account the health consequences for the populations exposed to environmental hazards. Despite the high level of Italian and international media interest in the problem of hazardous waste in Campania little has been done to reclaim the land and the waterways contaminated by hazardous waste.
Objective This study aims to reduce the uncertainty about health damage due to waste exposure by providing for the first time a monetary valuation of health benefits arising from the reclamation of hazardous waste dumps in Campania.
Methods First the criteria by which the landfills in the Campania region, in particular in the two provinces of Naples and Caserta, have been classified are described. Then the annual cases of premature death and fatal cases of cancers attributable to waste exposure are quantified. Finally

the present value of the health benefits from the reclamation of polluted land is estimated using the Willingness to Pay (WTP) approach. Due to the uncertainty about the time frame over which the benefits arising from reclamation last, the latency of the effects of toxic waste on human health and lack context specific WTP estimates extensive sensitivity analyses have been performed.

Results There are estimated to be 848 cases of premature mortality and 403 cases of fatal cancer per year as a consequence of exposure to toxic waste. The present value of the benefits in the Campania region arising from the reclamation of hazardous dumping sites (sites classified by Protezione Civile with a Waste Index higher than 1) is €9.400 million for premature mortality and €6.700 million for fatal cases of cancer.

Conclusions This study suggests that there is a strong economic argument for both reclaiming the land contaminated with hazardous waste in the two provinces of Naples and Caserta and increasing the control of the territory in order to avoid the creation of new illegal dumping sites.

Key words: toxic waste, environmental exposure, monetary evaluation, cost-benefit analysis.

Background

Uncertainty regarding waste generation, waste management practices, data on emissions, exposure characterization and, in particular, the health risk associated with the different types of waste management methods is the main cause of the extensive market failure in the management of waste disposal. Several population studies have documented (scientifically) that the mismanagement of waste disposal can have serious effects on the health and well being of the population [1-4]. A wide range of toxic substances can be released into the environment from waste disposal, for example, methane, carbon dioxide, benzene and cadmium. Many of these pollutants have been shown to be toxic for human health. IARC [5] classified exposure to cadmium and benzene as highly carcinogenic for humans. In addition if the waste disposals are illegal they are likely to contain highly hazardous compounds resulting from industrial production (e.g. asbestos, lead).

Two main health outcomes have been found to be statistically associated with waste exposure by

previous epidemiological studies: cancer and congenital malformations [6,7,1-3]. Hazardous waste has been shown to influence the likelihood of developing brain, bladder and lung cancer [9,10]. According to Dolk et al. [11] living close to a waste disposal site is also associated with a significant increase in congenital anomalies. They report an odds ratio of 1.33 (CI: 95% 1.11-1.59, adjusted for socioeconomic status and maternal health) for congenital anomalies among those living within 3 km of hazardous waste (landfill) sites in Europe. Bentov et al. [12] also found a significantly increased risk of central nervous system malformations for those individuals living close to toxic waste sites (1.63 CI;95% 1.34-1.80).

In the Campania region, in particular in the two provinces of Naples and Caserta, the absence of other types of waste management methods (composting, recycling, incinerators) and the extent of illegal toxic dumping of wastes were the main reasons for the waste crisis which started (officially) in1994, which in the last seven years has become known worldwide as a "tragedy" [13]. Campania has the highest number of environmental crimes in Italy and it has been estimated that 5 million tons of hazardous industrial residuals have been illegally discarded in the region [14]. According to WHO et al. [15] and Mutasem El-Fadel et al. [16], the waste-associated health hazards in this region have reached an unacceptable level and the problem now represents a real threat to human health.

Since the first research evaluating the relationship between waste exposure and excess of early mortality and congenital malformation there has been an increasing number of studies reporting a statistically significant relationship between waste exposure and human health in Campania [17-21]. The most recent study conducted by WHO et al. [15] in the provinces of Naples and Caserta documented higher rates of overall mortality, cases of fatal cancer and congenital malformations for those living in the area surrounding hazardous waste sites. For example, this study found that women who live close to waste disposals classified as the most toxic have a 12% increased risk of dying and 29% higher risk of developing liver cancer compared with those living in areas classified as environmentally safe.

To date, however, no studies have evaluated the economic health cost associated with toxic waste exposure in this region. Thus, the aim of the present study is to estimate the potential benefit from reclaiming the landfill sites in Naples and Caserta.

Method

The present study spans three main fields: environmental externalities associated with waste management, epidemiology and economics. The three steps to assign a monetary value to the health benefits arising from the reclamation of hazardous waste sites in Campania are shown in the flow chart (Figure 1). The starting point of the study describes the criteria used by the Italian Portezione Civile to classify the waste disposal sites in Naples and Caserta using a Waste Index (WI). The second part of the study quantified the annual physical impacts due waste exposure. Health outcomes have been estimated for each WI quintile using the exposure-response function from the WHO et al. [15] longitudinal study. Finally, the present value of the health benefits over a period of 30 years arising from land reclamation is estimated. The monetary values used to assign a value to a statistical life and to a case of fatal cancer have been selected according to European Commission recommendations and adjusted for the risk context and for different time frames of the predicted health benefits in the sensitivity analysis [22]

Classification of solid waste disposals in Naples and Caserta provinces

The impact chain shown in Figure 1 starts when waste enters the landfill or is abandoned (illegally) in the soil or in the water. Depending on the intrinsic quality of the waste and on the density of the population in the surrounding area hazardous emissions will be released into the environment affecting human health.

According to previous studies in Campania, the health risk due to environmental hazards arising from waste exposure is confined to the two provinces of Naples and Caserta where most of the illegal dumping sites are located [13-15]. The dumping sites in Naples and Caserta differ in dimension and composition. In addition, most of these waste disposals are illegal and not visible (sunken or buried) thus the toxic substances that the disposal contains are not known and difficult to identify. In order to map the possible areas exposed to a higher waste related health risk the Portezione Civile developed a synthetic index - the Waste Index (WI) [13]. Using a GIS system the Protezione Civile identified the areas of waste impact in these two provinces and classified each of the 196 towns according to the number of waste disposals present, the intrinsic composition of the waste disposals and the proportion of the population living in the areas

surrounding the dumping site. The higher the presence of toxic waste sites/population exposed the higher the WI assigned to the town.

Estimation of the Population attributable proportion due to waste exposure.

In order to estimate the incremental health outcomes arising from waste exposure each year it is necessary to evaluate the gradient of the dose-response relationship between WI and health outcomes observed after controlling for the socioeconomic factors [15, 23].

In Campania there have been several studies evaluating the effects of waste exposure on health that found a statistically significant relationship between the presence of illegal dumping sites and higher prevalence of cancers and congenital malformations [17-21]. The most recent longitudinal study (WHO et al., 15) collected mortality records on twenty causes of death (e.g. all cause mortality, all types of cancers, lung cancer, liver cancer, stomach cancer, non Hodgkin lymphomas) for each of the 196 towns of the Caserta and Naples provinces between 1994-2001. The relative risks of different health outcomes given different levels of waste exposure were estimated by Poisson regression after controlling for socioeconomic factors.

The population attributable proportion (PAP) of the overall cases of premature mortality and fatal cases of cancer due to waste exposure has been quantified using the results from this study. The number of cases (e.g. cancers) that would not have occurred in the absence of the environmental risk factor, for each health outcome and level of WI were estimated by the following formula:

$$PAP_{ab} = \text{Observed number}_{ab} - \text{Observed number}_{ab} / \text{Relative Risk}_{ab}$$

Where a is the health outcome and b is the WI quintile considered and Relative $Risk_{ab}$ the relative risk of developing a given health outcome a (e.g. premature death) for each WI quintile b after controlling for socioeconomic factors [23, 15, 24].

Assuming that the effects of waste exposure on human health are equally distributed over time, the yearly number of health outcomes attributable to waste exposure is given by dividing the PAP of each health outcome by eight (the number of years of the longitudinal study).

Monetary valuation of the health benefits arising from land reclamation

According to the Enhealth-guidelines [25] there are two main methods for evaluating health: the human capital and the willingness to pay approach. The human capital approach assumes that the value of an individual's life to the society can be measured by future production potential, for example, future labour earnings. Based on the human capital approach, the Cost of Illness (COI) method measures ex post the costs arising from a specific negative health outcome, including the cost of hospitalization, consultation, death [26]. Although this approach takes into account all the direct costs associated with a given disease it does not include the intangible costs: pain, discomfort and depression that are associated with an adverse health outcome and, especially for a very serious health outcome, it tends to underestimate the true cost of the disease. Another weakness of the COI approach is that it is an ex post measure of costs and it does not consider the value that individuals attribute to possible risk reduction interventions.

For these reasons the WTP approach has been adopted. It is the most commonly used method in the evaluation of environmental health effects as it measures ex ante how much individuals are willing to pay for a reduction in the probability of an adverse event.

Since the WTP approach has not been used to value a statistical life in Italy, nor in the context of waste exposure, this study uses values suggested by the European Commission [22]. These estimates: 3.7 million Euros as upper value, 1.4 million Euros as baseline estimate and 0.95 million Euros as lower value, have been re-expressed in 2007 prices using the Harmonised Index of Consumer Prices [27]. There are two main benefits to using the values suggested by the European Commission [22]: they have been adjusted for the age of victims of environmental pollution and they can be applied to all the EU countries.

Several studies report that the WTP to avert a case of cancer is higher than the WTP for reducing the risk of a fatal trauma in transportation accidents [22, 28, 29]. Cancer is associated with a long period of serious illness and a high burden of pain and discomfort. Thus, because of the "dread" of such a long period of suffering, individuals tend to place a higher WTP on averting a fatal case of cancer than a case of premature but less painful death. In this study, according to the EC guidelines, the values (upper, baseline and lower estimates) of a statistical life used for a case a premature mortality have been increased by 50% in order to account for the cancer premium (the increased WTP of individuals arising from the dread of the illness). Thus, the

estimates that have been used are 5.55 million Euros, 2.1 million Euros and 1.42 million Euros as upper, baseline and lower values respectively.

The formula used to estimate the present value of the health benefit arising from reclaim polluted waste sites is reported below [30]. It treats X_a the estimated annual number of health outcomes a as an annuity lasting t years. This is re-expressed as a present value using the discount rate d. This future present value of an annuity is then itself discounted to take account of the latency period l, which is the time between the emission cessation due to site reclaim and the effective reduction of the health outcomes due to waste exposure. λ is the WTP for the health outcome a.

$$PV= \lambda *X_a*(1/1+d)^l*(1-1/(1+d)^t)/d$$

In the baseline scenario three assumptions have been made: the benefit to human health from reclamation of waste sites lasts 30 years; the discount rate is 4 per cent; and the latency period (the delay between the reclaim of the land and the effect of the cessation of hazardous waste exposure on human health) is 20 years. As per EC [22] recommendations sensitivity analyses were carried out considering different time frames for heath benefit arising from land reclaim (10, 20 and 50 years), a 2 per cent discount rate and different latency periods (10 and 30 years).

Results

Number of waste attributable cases

The results of the epidemiological section are shown for each health outcome separately for men and women. The estimated Relative Risk of developing the health outcome with respect to the first quintile (which contains the towns least exposed to negative externalities from waste exposure) are reported in the second column of Table 1. The third column contains observed cases of the health outcome from 1991-2001. The fourth column shows the estimated PAP. Only cases resulting from a statistically significant ($p<0.05$) RR were considered. Finally the last row reports the number of cases attributable to waste exposure each year for both sexes. According to the WHO et al. (2007) study men living in the second, third, fourth and fifth WI

quintiles have 5%, 8%, 4% and 8% higher risk of dying compared to men living in the areas least exposed to waste. Women are even more exposed to the effects of waste than men as the RRs for each WI class are higher compared to men in all quintiles except the second. Of the 89,530 deaths observed among men in these four quintiles between 1994-2001, 4,580 are associated with waste exposure. Among women the overall number of deaths is 85,018 and the number of waste attributable deaths is 2,200. The total number of fatal cases attributable to waste exposure each year in the two provinces of Naples and Caserta are 848.

Among men an increased risk of developing a case of fatal cancer is observed across all the four quintiles with the exception of the fifth where the risk is not statistically significant (Table 2). Among women only those living in the towns included in the second and the fifth quintiles show an increased risk of dying by 5% and 7% respectively. The overall number of cancers observed is 72,674 of which 3,222 are attributable to waste exposure over an eight year period resulting in an estimate of 403 cases per year.

Health costs due to waste exposure.

In Table 3 the present value of the health benefits attributable to waste sites reclaim are reported assuming a time frame over which benefits are displayed of 30 years, a 4% discount rate and 20 years of latency. All costs are reported in millions of Euros. The yearly population attributable proportion (for both sexes) has been reported for each of the health outcomes.

The overall number of waste related deaths (from all causes) per year is 848. The overall benefit given the base case assumptions is €9.400 million. Although the cases of fatal cancer are significantly lower (less than 50% of the all cause deaths) the overall cost of fatal cancer cases associated with waste exposure is high: (6.700 million €) because of the "cancer premium" whereby the cost of one case of fatal cancer is 50% higher compared to other types of death not preceded by a long period of illness.

Sensitivity analysis

Different assumptions about the latency of the effect of the pollutants and about the discount rate lead to different conclusions about the overall effects of toxic waste on human health. There are no epidemiological studies that evaluate the latency of toxic waste effects on human health. The presence of illegal toxic waste sites in Campania is documented since the 1980s thus it is not possible to infer from the epidemiological study conducted by WHO et al. (2007) whether the excesses in premature mortality, cancers and malformation are the consequence of a recent or long exposure to waste emissions. Health benefits arising from land reclamation in Campania are reported below assuming different time frames over which benefits are displayed and adopting different latency periods using both a 4% discount rate and a 2% discount rate, as per current EC (2001) recommendations (Tables 4 and 5).

Limitations of the study

Several assumptions have been made during the course of this investigation. According to the Protezione Civile [13] the potentially toxic waste sites located in the Campania region are concentrated in the area of Naples and Caserta provinces. However, it is very likely that there are other sites outside that area that have not been documented so the problem is likely to have been underestimated. In terms of epidemiology, the specific effects of the single pollutants on health were not considered thus the transferability of the results of the present study to contexts that differ from the Campania region is limited.

In addition, the health related effects considered were only the long term effects arising from waste exposure (death and cancer). Although, several short term effects have been associated with toxic waste exposure such as malformations, asthma and respiratory infections these were not considered in the economic evaluation. As a consequence, the health outcomes associated with waste exposure are underestimated. Further research is needed to provide a more comprehensive evaluation of the health effect of waste. The Willingness to pay values used are those suggested by the EC [22].

Since they are adjusted for the age of mortality victims of environmental pollution they provide a better estimate compared to previous VSL studies, however, they have not been elicited in the context of waste associated health risk.

Discussion

Better data collection and the increasing number of epidemiological studies have increased public awareness of the long term health effects associated with negative environmental externalities[31]. Assigning a monetary value to health risks arising from environmental externalities allows all the environmental influences on human health to be formally quantified and should allow decision makers to deliver optimal policies aimed at reducing the "external cost" to society. In recent years there has been increased attention towards the use of cost benefit analysis for the evaluation environmental interventions aimed at reducing the health damage associated with health pollution. Despite this, little has been done to quantify the external costs due to environmental hazards on health although they account for a large part of the damage associated with negative externalities.

Most of the studies conducted in both developed and developing countries on the effects of environment on human health have focused on the long term effects of air pollution on mortality and morbidity and little attention has been paid in evaluating the economic costs of waste related health effects [24,32-,35].

The results of the WHO et al. [15] study conducted in the Campania region suggest that in Naples and Caserta, the presence of toxic waste disposals is associated with an increased level of mortality, fatal cancers and some types of congenital malformations. Using WHO et al. [15] data this investigation estimated that between 1994 and 2001 6,781 of the overall 174,500 deaths in the region have been found to be associated with waste exposure. Looking at the specific causes of death, 3,222 fatal cancers in the eight year follow up of the WHO et al. [15] study were estimated to be associated with waste exposure – an estimated 403 cases per year.

Thus, according to the Willingness to Pay approach the present value of the health benefits arising from the reclamation of waste sites in the provinces of Naples and Caserta is €9,400 million and €6,700 million for premature mortality and fatal cancer respectively.

As EU [36] suggests the majority of the research conducted in the field of waste focus only on the tangible cost of waste management method and not the intangible benefits that can result. As long as the real costs and benefits of waste management policies, including their impact on health, are not explicitly accounted for in economic evaluations, there is a risk that poorer policies will be adopted and better policies rejected. It has been estimated in the two provinces

of Naples and Caserta there were 1,230 estimated illegal dumping sites in 2004 and that number of illegal dumping sites increases every year by 30% [18].
Neglecting the health costs arising from waste exposure in Campania would result in further (tangible and intangible) costs for the Italian Health care system and for those individuals that experience premature mortality and /or a long period of severe morbidity.

Competing interest

'The authors declare that they have no competing interests

Authors contribution

CG performed the literature review, drafted the manuscript and carried out part of the analysis. JC contributed substantially to defining the methods of the analysis, interpreting the results of the study and revising the manuscript for publication.

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Abbreviations and definitions used in the manuscript

WTP willingness-to-pay
WI Waste Index
EC European Commission
PAP population attributable proportion
COI the Cost of Illness method
VSL value of a statistical life

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Tables :

Table 1. All causes mortality

	Waste index	Relative Risk	Observed cases	PAP
Male				
	2	1.05[a]	53106	2528
	3	1.08[a]	7853	580
	4	1.04[a]	20130	774
	5	1.08[a]	8459	698
Female				
	2	1.02	52167	1023
	3	1.08[a]	7124	528
	4	1.05[a]	18226	868
	5	1.12[a]	7501	804
Cases per year				848

a p value <0.05

Table 2. All fatal cancers

	Waste index	Relative Risk	Observed cases	PAP
Male				
	2	1.04[a]	15989	615
	3	1.06[a]	2297	1658
	4	1.05[a]	6261	298
	5	1.04	2525	97
Female				
	2	1.05[a]	11435	544
	3	1.02	1490	30
	4	1.04	4038	155
	5	1.07[a]	1639	107
Cases per year				403

a p value <0.05

Table 3. Health benefits arising from waste sites reclaim

Item	PAP per year	Costs (million €)[a]
All causes mortality	848	9,400 (25,000-6,300)[b]
All fatal cancers	403	6,700 (17,000-4,500)[b]

[a]costs have been discounted at an annual rate of 4% assuming 20 years latency.

b Upper and Lower estimates obtained using upper and lower values suggested by the EC [22].

Table 4. Health benefits assuming different time frames for benefits

Item	50 year time	20 year time	30 year time
All causes mortality	17,000 (31,000-8,000)[a]	7,000 (19,000-5,000)[a]	4,000 (12,000-3,000)[a]
All fatal cancers	8,000 (22,000-7,000)[a]	5,000 (14,000-3,000)[a]	8,000 (13,000-2,000)[a]

a Upper and Lower estimates obtained using upper and lower values suggested by the EC [22].

Table 5. Health benefits assuming different latency periods and discount rates

Discount rate	Item	10 year latency	20 year latency	30 year latency
4%	All causes	14,000	9,400	6,300
	mortality	(37,000-9,400)	(25,000-6,300)	(17,000-4,300)
	All fatal cancers	9,900	6,700	4,500
		(26,000-6,700)	(17,000-4,500)	(6,800-3,000)
2%	All causes	22,000	18,000	15,000
	mortality	(58,000-16,000)	(47,000-12,000)	(39,000-9,900)
	All fatal cancers	15,000	33,000	10,000
		(41,000-10,000)	(13,000-8,600)	(27,000-7,000)

a Upper and Lower estimates obtained using upper and lower values suggested by the EC [22].

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Figures:

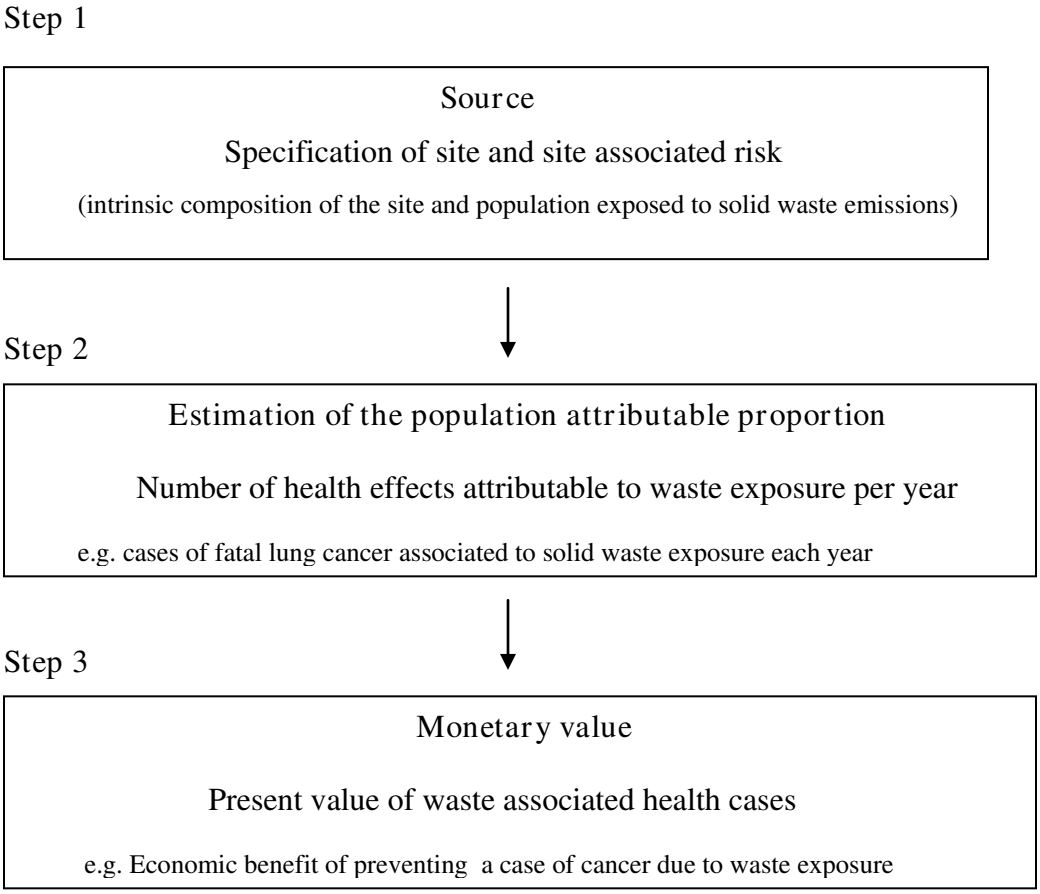

Figure 1. Method used to evaluate the monetary benefits of waste sites reclaim.

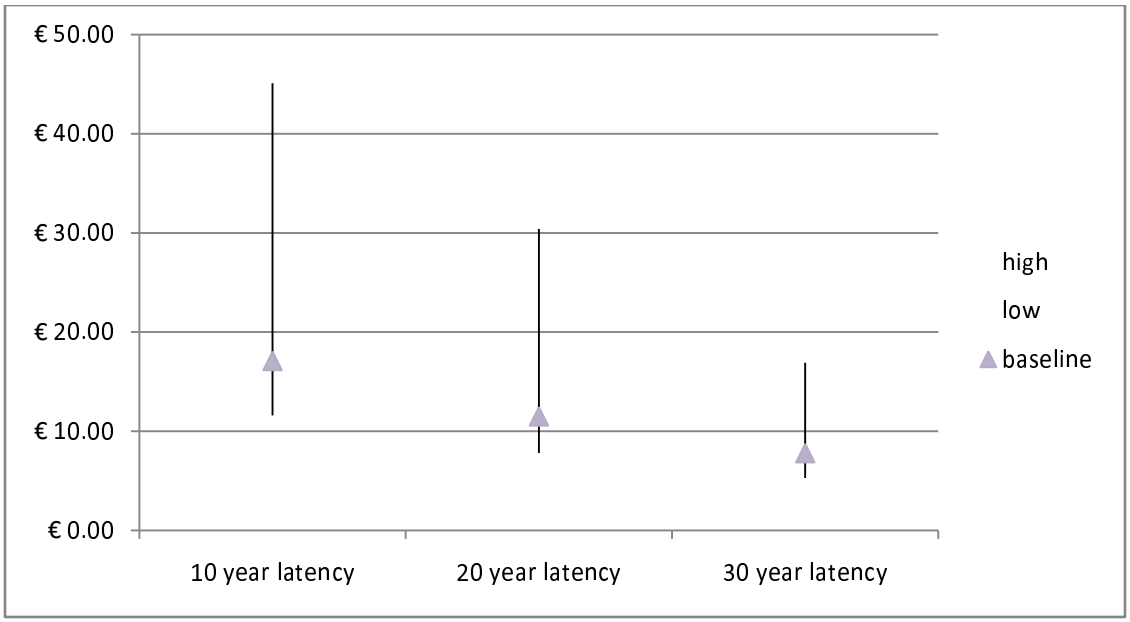

Figure 2: Monetary benefits (*billion€) assuming different latency period*s and a 4% discount rate.

Figure 2

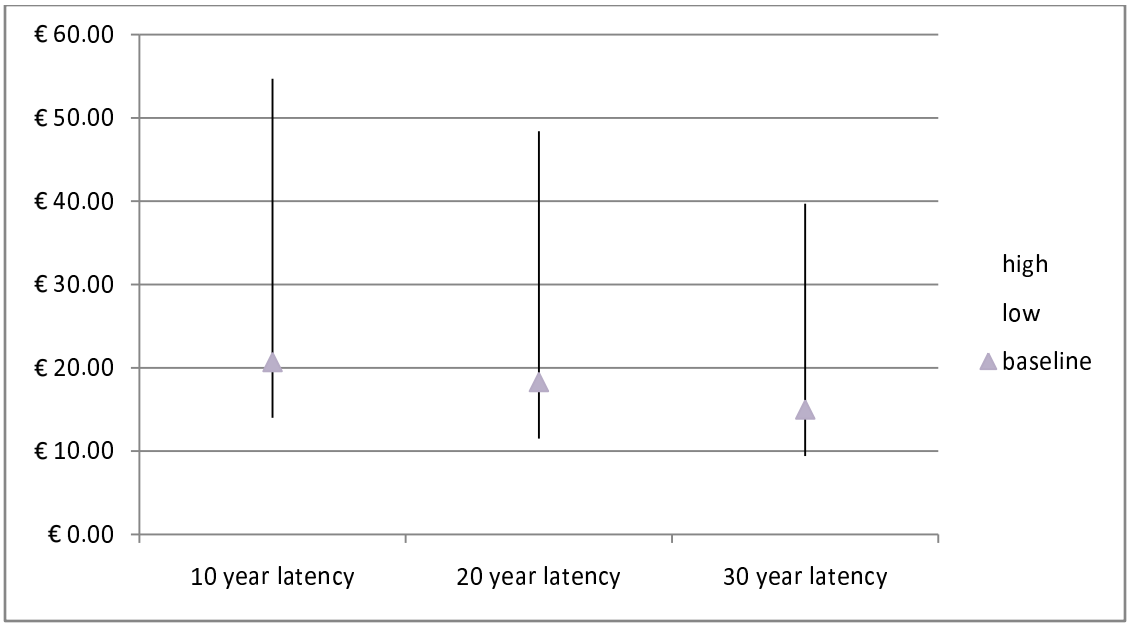

Figure 3: Monetary benefits (*billion€) assuming different latency period*s and a 2% discount rate.

Figure 3