Historical Social Research, Vol. 32 — 2007 — No. 4, 222-251

Water, Public Hygiene and Fire Control in Medieval Towns: Facing Collective Goods Problems while Ensuring the Quality of Life

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Abstract: *»Wasser, öffentliche Hygiene und Brandschutz: Zum Problem des Managements lebensstandardrelevanter Kollektivgüter in der mittelalterlichen Stadt«*. Clean water, neat streets and fire prevention determined the quality of life also in medieval towns. While ensuring an environment worth living citizens were faced with collective goods problems. As a result of the environmentally harmful urban way of life common-pool resources like waters and streets were over-exploited, polluted and degraded. This *urban tragedy of the commons* was even more complicated, as public hygiene and fire prevention, both necessary to cope with pollution and fire hazard, were public goods and their realisation caused a *public goods dilemma*. Due to coordination efforts – municipal administration, transfer of property rights, enhancement of voluntary cooperations and regulations – common-pool resources like water and infrastructure could be provided, but municipal authorities barely succeeded in enforcing polluters to internalise the social costs of their behaviour and managing the supply of public preventive goods. Differently from the suggestion made in the concept of *Environmental Kuznets Curve* emergence of environmental externalities and treatment of communal risks were not only related to economic development, but also to population growth.

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1. Introduction: water supply, public hygiene and fire prevention in medieval towns and their relevance to the quality of life

The provision of citizens with clean water, streets and lanes that are kept neat and the protection of the community from fire hazard were vital components of the quality of life that could be enjoyed in medieval towns. Fresh water was of course used as drinking water, but was also needed for brewing and slaughter. It has been in particular a factor of production necessary to crafts such as the dyeing or the tannery and was exploited for grain-grinding by water milling (Guillerme 1988: 52). Enforcement and maintenance of public hygiene were of importance, because the spread of plague and other infectious diseases which put at risk the population as a whole was obviously promoted by the urban dwellers' practice of using streets and waters for the disposal of excrements, animal carcasses and all other sorts of waste (Jankrift 2003: 151-166). Finally, as a fire presumably was the highest risk for the physical basis of urban settlements, and damages due to town fires were extremely costly to repair, the omnipresent hazard coming from the use of open fire (Jankrift 2003: 86-89). had to be handled in order to guarantee urban dwellers a minimum quality of life at least.

Why common waters in towns managed quite intensively were rather early in medieval history, but public hygiene and fire prevention even in the later Middle Ages were often not ensured sufficiently? How did communities cope with the polluting and endangering behaviour of inhabitants? Who was in charge of it, and what made people become aware of the communal risks they produced by a way of life that in every aspect was environmentally harmful? Discussing these questions, concepts dealing with economic characteristics of goods, with social dilemmata and environmental economics will be used. Yet, before stepping into analysis, two points have to be mentioned briefly, the historical development of urban communities during the Middle Ages and the role goods, in a wider theoretical meaning of the word, played for civic life.

The high Middle Ages saw a resurgence of urban settlements all across Europe. It would probably be too much of a simplification of the quite heteregenous pattern of urbanisation to assume a uniform path of urban development. This notwithstanding some general statements nevertheless can be made. The revival of urban culture in Europe, after it had nearly ceased with the decline of the Roman empire in late antiquity, was promoted certainly by a sustained population growth that was due to an improvement in climate and an increase in agricultural productivity from the 11th century onward (Lopez 1998: 27-55). This economic upward shift allowed a quite small but nevertheless significant part of the population to be not obliged to spend their working efforts on the production of basic foodstuffs only. Instead these people could make their life

residing in towns and producing, refining and trading all sorts of commodities and services, because food-wise they could rely on the surplus of produce that was made by a still further growing rural population. Only in a smaller number of places the emerging urban settlements were built upon the remnants of antiquity (Ennen 1987: 31-50; Guillerme 1988: 23-50). Many towns were newly founded ones, being under the rule of lay or clerical feudal lords who had granted economic privileges and a municipal law to the urban settlers (Ennen 1987: 118 f.). Subsequently thousands of towns arose and evolved all across Europe until the early 14th century. Having well started under the auspices of feudal authorities, urban communities soon became, as a result of the social dynamics unfolding with their economic success, economically, politically and socially an alternative model to feudalism. In contrast to the hierarchical structure of the rural society the basic idea of urban culture was that of a political equality of the community members. Urban communities then attempted both to liberate themselves from their feudal lords and to put down their political rights in written constitutions.[1] Although a complete liberation from feudal rule rarely could be achieved – lay and clerical feudal lords commonly stayed in a *de jure* position of ownership for quite a long time – feudal authorities nonetheless had to accept that towns and cities had become rather independent political actors, at least with regard to issues of communal organisation.

The present approach is motivated by a goods paradox existing for medieval urban communities. Whereas economic rise of towns during the high Middle Ages and citizens' accumulation of individual wealth were clearly based on handling private goods, civic life in contrast was shaped by different collective goods, these either being common-pool resources such as waters and streets or public goods like public hygiene and fire prevention. Forming communities *per se* meant for every member to enter into collaboration with others concerning the various aspects of daily life. As many resources and services could be used collectively, urban communities were confronted with a multiple collective goods dilemma and needed a management scheme to handle this problem. The goods paradox is obvious insofar as the literature on medieval urbanisation mainly focussed on the private economic goods aspect, namely production and trade, and its collective organisation in guilds. Even in studies on water supply the presence of collective goods and the difficulties arising from it are acknowledged, but are not sufficiently treated as what they are – a fundamental problem of organisation (e.g. Guillerme 1988; Squatriti (ed.) 2000; Leguay 2002). Surely, medieval towns often did not possess the kind of sophisticated technologies that had been in use in antiquity, regarding water supply for instance. Yet, it seems as if towns with their representative comportement put the

[1] The earliest of these attempts can be grasped in the Northern Italian cities during the 11th and 12th centuries, but the same kind of movement was under way in other European regions in 13th and early 14th centuries. (Ennen 1987: 137-144).

emphasis more on the economic strength they had gained and the impressive results of municipal efforts, namely majestic city walls, high cathedrals and representative town halls (Boockmann 1994: 35; Grewe 2000: 131) – all these items representing the abstract public good of urban freedom –, rather than taking care of communal services such as water supply, waste disposal or the maintenance of public hygiene.

Water management (Guillerme 1988; Benoit/Wabont 1991; Grewe 1991; Squatriti (ed.) 2000; Leguay 2002), pollution and hygiene (Kühnel 1984; Dirlmeier 1986; Boockmann 1994; Leguay 1999; Schubert 2002; Jankrift 2003) in medieval towns are not new subjects to the literature, indeed. These issues were described in detail for a variety of cities in medieval Europe. The new aspect added herein to the current knowledge about this topic is the analysis of the communal risk management problem within an economic framework, an approach explicitly based on the rational-choice paradigm, and for this particular issue cannot be found in the literature so far. The approach is related to studies of Volckart (2004) and Lehmann (2004), who used rational-choice and economic concepts for their research into collective action in medieval village communities and into the rent seeking of the social élites in medieval and early modern Nuremberg, respectively. The aim here is to draw some general conclusions from medieval urban history regarding the communal risks being relevant to the quality of life, rather than describing a historical case in detail. Three points shall thereby be made: The fundamental problems arising in the provision of inhabitants with quality-of-life-ensuring collective goods is described in section 2. A typology of solutions found to this problem is given in section 3. Changes over time in dealing with communal risks and public preventive goods will be discussed in section 4 with respect to population growth and economic development.

2. The problem: negative externalities and collective goods dilemmata

2.1 Negative externalities as a result of the urban way of life

In many respects the way of life practised in medieval towns was environmentally extremely harmful. First of all, the various crafts were characterised by countless water and also air polluting activities through which chemicals and organic materials were put into brooks, rivers and common waters, or stench was produced like in the case of the tanneries, abatoirs or breweries. A second major problem for the environment in towns concerned all kinds of waste. Spent water from households, kitchen slops and excrements were commonly deposited directly in the streets (Guillerme 1988: 116). Although for instance

in Northwestern German towns market places already had been paved, in 15th century the pavement was covered with a thick layer of organic waste (Schubert 2002: 106, on Hannover; Jankrift 2003: 152, on Soest). The amount of excrements was increased due to the practice of keeping animals in the backyards of houses, but also in the streets (Delort 1989; Boockmann 1994: 84; Jankrift 2003: 161-166). Because cemeteries were located inside towns, water table and wells were constantly contaminated (Guillerme 1988: 116; Jankrift 2003: 174-177). A third problem arose from the widespread use of open fire in the houses which was needed in production processes and of course for cooking and heating (Jankrift 2003: 86-89).

The environmental effects of this practice obviously reduced the quality of life. These effects also were in a sense communal risks, because by endangering either public hygiene or the physical integrity of houses, pollution and fire hazard put at risk the existence of the whole community. A town fire destroying many homes or the spread of diseases, fostered by contaminated water and filthy streets, were severe challenges to civic life. Using an economic term, these environmental impacts or communal risks were negative externalities. Externalities in general are those effects of human behaviour, which come as a rather unintentional side effect of it and thus are not relevant to the actor's utility calculation, but nonetheless affect other actors by either providing them with benefits or causing costs to them (Gravelle/Rees 2004: 319 f.). Communal hazards in medieval towns were negative external effects of the urban dwellers' daily life activities, because putting people at risk with pollution or fire certainly was neither the clear aim nor an intended consequence of these activities, it simply was a costly byproduct.

2.2 Collective goods within the medieval town

In a very general meaning of the word, collective goods are defined as being non-private and allowing a collective use. Economic characteristics of goods can be distinguished using the cross-classification of a good's excludability versus its substractability (Dionisio/Gordo 2006: 323). Private goods are both substractable and excludable. In contrast, pure public goods (Olson 1965; Buchanan 1999) are neither substractable nor excludable. Once a pure public good is produced, the good itself is not depletable and the marginal benefit consumers derive from it is constant for anybody. Thus, there is no rivalry between the consumers of a pure public good. Also, no potential consumer can be excluded from consumption, either because it is impossible or is too costly to get accepted. Besides the conventional private good and the pure public good two other ideal types of goods do exist, which both can be used collectively. If a good for instance is excludable but not substractable, one speaks of a club good. Like a pure public good it is not depletable, but consumption can be restricted to the members of a »club«, who pay a fee in return for their privilege

of consuming the good. Vice versa, if a good is substractable but not excludable, it is a common-pool resource, meaning that it is open to everybody but itself is depletable.

Inhabitants of medieval towns dealed with various types of private goods indeed. These were the foodstuffs, commodities and services that either were consumed or produced, refined and traded by them. Wealth in towns thus was based mainly on the exchange of private economic goods, but daily life was shaped by a variety of collective goods, not necessarily always being physical objects, anyway. Some of these collective goods such as the streets or common waters were of material nature. Some others like civil rights, jurisdiction, price stability (Persson 1999: 72) or even the notice of time on public clocks (Dohrn-van Rossum 1992) were intangible because of their immaterial character. A town's defense is an illustrative example of a non-material collective good – defending the community's integrity – to be materialised in a physical collective good – the massive town walls, probably the best-known symbol of the medieval European town, that in many places were constructed in 12th to 14th centuries to protect everyone living inside these walls.

In using the typology described above different kinds of medieval urban collective goods can be distinguished. Water and streets were typical common-pool resources, and they were subject to pollution, which of course is one aspect of depletion. Political participation rights or even economic privileges in turn were club goods, because only those urban dwellers who had the formal status of being a citizen could benefit from these goods.[2] Inhabitants without such a qualification, and there were many of them, had no access to these goods. In contrast, public hygiene, protection against fire hazard or price stability on the local grain market were public goods. Everybody living in the community, no matter whether he was a formal citizen or not, was to benefit from this, without reducing the marginal utility of other inhabitants. Nobody could be excluded from consumption, and for public hygiene or fire control this was not wanted either, since these public preventive goods were vital elements in the protection of civil life. They were needed to cope with the negative externalities produced by urban dwellers, these effects being public goods as well. At first glance, the term »good« seems to be a misnomer with regard to pollution and fire hazard, because nobody really wanted to consume this kind of good. Being a subject to such risks, everybody nonetheless had to.

Dilemmata with respect to the supply and the management of goods will arise if goods are non-excludable. Yet, the quality of life in medieval towns was based to a large extent on the management of collective goods. While using or misusing common-pool resources such as waters and streets, inhabitants directly influenced the environmental component of their quality of life. Hence, the management of quality-of-life-securing collective goods was about

[2] Privileges and services merchant and craft guilds provided for their members also were club goods inasmuch as the benefit of these goods was limited to members.

dealing with common-pool resources, communal risks and preventive means. Ensuring an environment worth living meant to tackle a twofold collective goods dilemma that was related to the supply and exploitation of common-pool resources and the provision of public preventive goods.

2.3 The urban tragedy of the commons

Pollution and depletion of the town's common-pool resources were visible results of the environmentally harmful production methods and the inhabitants' way of life. These negative externalities point to a more general pattern of a degrading treatment of the environment which aptly could be labelled the medieval urban tragedy of the commons. The term tragedy of the commons was first formulated by Hardin in 1968.[3] Following this theorem, without a proper management and the formulation of generally binding rules, common-pool resources will be over-exploited. Moreover, if devices are necessary to make a common-pool resource available to a larger number of users, like in the case of water in medieval towns, nobody would deliberately provide such devices due to strong incentives to free-ride on others' investments (Volckart 2004: 28). As it is a non-exclusive but depletable and scarce good, the natural environment is the classic example of a common-pool resource being prone to over-exploitation. More generally, risk-free surroundings were a common-pool resource in medieval towns that by producing hygienic risks and fire hazard were constantly degraded. The reason for the users' degrading behaviour in such a situation is a mis-specification of the incentive structure they face. All of them directly receive utility from using the resource, in medieval towns for instance by draining off their sewage into common waters or depositing their waste in the streets, but as those refraining from doing so are not rewarded, there is no incentive for anybody to change behaviour such that it would do less harm to the environment.

The concept was criticised for ignoring two points: it has been argued, that in contrast to the initially made assumption of being a non-exclusive good, historically for most common-pool resources its use in fact was limited to a small group of individuals, and that rules for the use were applied, minimising the problem of a potential over-exploitation (Ostrom 1994; Ostrom et al. 1994). It cannot be denied, that these objections are correct, and Hardin (1994) himself later on coined the probably more precise term of the *unmanaged tragedy of the commons*. For its present application to water supply, pollution and other communal risks in medieval towns, the theorem is nonetheless of instructive value, because it stresses the necessity of management routines for the town's infrastructure. Although in the medieval case these resources were used by a

[3] In fact, the understanding of common property being prone to neglect and misuse dates back to the ancient greek writers Thucydides and Aristotle.

well-defined group of individuals – the town's inhabitants –, group size could very well grow to a number such that negative environmental externalities were intensified and subsequently common-pool resources could easily be damaged or depleted.

As the medieval *urban tragedy of the commons* was related to pollution and other communal risks, concepts recommended to minimise negative externalities are of interest. Typical solutions discussed in environmental economics are governmental regulations proscribing polluting activities, tradeable emissions permits, tariffs on pollution or the entering into contracts (Hodge 1995; Hanley et al. 2001). These means help to convert the social costs of a negative externality into individual costs to be payed by the perpetrator of this effect. This is called internalisation of costs (Gravelle/Rees 2004: 319-323). In the example of pollution in medieval towns this would mean that instead of depositing waste directly in the streets and leaving fellow citizens with the disgusting stench and the hygienic hazards coming from it, everybody would have faced an incentive to refrain from such an activity, if one has had to pay for it. All means proposed do have two prerequisites in common: the existence of an authority capable of monitoring environmental effects, defining rules, taxing pollution and enforcing contracts, and the assignment of well-defined property rights over the common-pool resource. This especially becomes clear in the *Coase theorem* (Coase 1960). In principle the polluter and the person concerned by pollution should always be able to sign a contract by which the internalisation of social costs is guaranteed, as long as property rights are defined, the full extent of negative externalities is known and negotiation costs are irrelevant (Gravelle/Rees 2004: 320 f.; Volckart 2004: 25). Since in medieval towns the perpetrators of risks and those concerned were not only numerous, but often also identical persons, a bilateral contractual solution seems quite unrealistic. Nevertheless, this result helps understanding medieval cases insofar as it points to the importance of a property rights definition, of knowledge about the environmental impacts of human behaviour and of potential barriers to the balance of conflicting interests.

2.4 The public goods dilemma with respect to public hygiene and fire control

In principle, negative externalities such as pollution or fire hazard leading to an urban tragedy of the commons could have been faced by maintaining public hygiene and organising a preventive fire protection. In both cases voluntary cooperation of urban dwellers was needed. Communal risks could have been reduced by changing behaviour to a more careful treatment of the environment, and by investing in preventive means. Prevention could have been ensured by cleaning streets, paving them, so that they can easier be kept neat, or in the case of fire hazard, by handling fire with care, building stone houses instead of

wooden ones and having devices at hand which facilitate fighting a fire, such as buckets, ladders or fire crooks (Jankrift 2003: 91). Since prevention was a public good, its supply could have been complicated due to a public goods dilemma arising. The incentive structure urban dwellers faced, making them unwilling to contribute voluntarily to a reduction or even avoidance of communal risks, is analysed using the game theoretical model known as prisoners' dilemma (Kreps 1990: 28-29, 37-39). Following assumptions are made in this game: players (urban dwellers) receive utility if public hygiene or fire protection are guaranteed. They can simultaneously choose either to contribute to public hygiene – by avoiding hazardous waste deposit, cleaning or paving streets, for instance – or fire protection – by using fire with care, buying fire fighting tools or making houses fire-proof, for example – or not to make such investments. Players seek to maximise their individual utility level and are eager to avoid risks. By taking into consideration possible actions of other players they also act strategically. Entering into contracts is impossible, and also institutions do not exist by which conflicting interests could be coordinated or mutual agreements would be enforced.

A simple game for players *A* and *B* is defined as follows: Costs C_A and C_B are the players' individual contribution to the maintenance of a certain level of public hygiene, for instance.[4] In a cooperative solution both players accept to bear an equal share *TC/2* of total maintenance costs $TC = C_A + C_B$, but each of them is willing to pay the amount of $WP_i \geq TC/2$, if that level of public hygiene could be realised. There are two differences to the classic public goods problem[5]: differently to the production of knowledge for instance, here the public good (hygiene) cannot be generated by the efforts of one player only, simply because this would be too costly. Thus, both WP_A and WP_B are definitely below *TC*. Moreover, public hygiene can only be realised if all players are contributing to its maintenance. In addition, a failure in maintaining a certain level of public hygiene would cause health risks. As a consequence, the absence of the public good is felt by the players as a disutility $-U_i$, and in fact they are at risk if public hygiene cannot be guaranteed. The amount of disutility cannot be clearly specified, but assuming risk aversion it certainly is below *0*, and even if players are not aware of the hygienic risks coming from contaminated water and filthy streets, this value would equal *0* at best. Naturally, the rather abstract willingness to pay can only be converted into utility if the public good concerned is actually generated. In the cooperative solution utility is calculated by subtracting individual costs from the willingness to pay ($WP_i - C_i$). For the remaining potential outcomes where public hygiene will not be generated, because at least one player is not contributing, players would face a disutility $-U_i$, and in case they would decide to contribute while the other would not, also

[4] Exactly the same setting applies to the organisation of fire prevention and fire protection.
[5] This problem is described in terms of the *prisoners' dilemma* in Holler/ Illing 1996: 8 f.

had to write off their own share of costs. Utility levels are displayed in the pay-off matrix of Table 1.

Table 1: Pay-off matrix of a two-player public preventive goods realisation game

		Player **B**	
Player **A**	*contributing*	*not contributing*	*Min. (A)*
contributing	A: $WP_A - TC/2$ B: $WP_B - TC/2$	A: $-U_A - TC/2$ B: $-U_B$	$-U_A - TC/2$
not contributing	A: $-U_A$ B: $-U_B - TC/2$	A: $-U_A$ B: $-U_B$	$-U_A$
Min. (B)	$-U_B - TC/2$	$-U_B$	

For the two-player game, the result can easily be derived from the behavioural assumptions that are made. For the purpose of maximising own utility but minimising risk both players will play a *min-max-strategy*, that is, they will opt for the best result of their personal worst cases, which is not to contribute.[6] Players' acknowledgement of the positive value public hygiene has and also a strong disutility due to lacking public hygiene are insufficient conditions to finally attain neat streets and surroundings free of risks. The problem is not caused by free-riding as in the case of the classic *public goods dilemma*. Since by definition public hygiene cannot be ensured without all players contributing, free-riding is impossible here. Players will not contribute, because they fear that their personal investment would be useless. Keeping the street in front of the own house clean by no means will reduce the hygienic risk if the other is not doing the same. As the public preventive good »public hygiene« will not be realised, this outcome, called the *Nash-equilibrium* (Kreps 1990: 28-36), is not an optimum result of course, neither with respect to individual nor to overall utility. If both players decided to contribute, they would be better off individually as well as community-wise. This notwithstanding, refraining from contribution is nonetheless a rational decision given the behavioural assumptions of the game.[7] The much better result of both parties contributing[8] can only be attained by third-party-enforcement or mutual trust, elements missing in this particular setting.

[6] Not to contribute gives the maximum of the minima, which is $-U_i$, respectively, players *A* and *B* would have to face with regard to the other players possible decision.

[7] Even if players do not acknowledge the benefits from public hygiene ($WP_i = 0$) and do not perceive hygienic risks as such ($-U_i = 0$), the outcome will be the same.

[8] With $WP_i \geq TC/2$ and $-U_i$ the cooperative solution of the game is *Pareto-efficient* insofar as neither of the players can improve the own utility level, and therefore also cannot be better off without decreasing the other's utility level (Gravelle/Rees 2004: 283 f.).

The game can be easily extended to the more realistic case of *n* players. For each player the willingness to pay for the maintenance of public hygiene remains below total cost ($WP_i < TC$), but again is greater or equal the individual costs of contribution (TC/n). Differently from the two-player-game, now for generating the public good not all players involved necessarily have to decide to cooperate. Public hygiene nonetheless can only be realised if a considerable number of players contribute. Public hygiene is not guaranteed if only a few urban dwellers would refrain from depositing their waste in the streets.[9] Utility levels for each player *i* are calculated in exactly the same way as in the two-player game (see Table 2 for pay-offs).

Table 2: Pay-offs for player i in a n-player public preventive goods realisation game

	Number j of other players contributing						
Player **i**	*n – 1*	*n – 2*	…	*n – …*	…	*0*	*Min. (i)*
contributing	$WP_i - TC/n$	$WP_i - TC/(n-1)$	…	$U_i - TC/n$	…	$U_i - TC/n$	$-U_i - TC/n$
not contributing	WP_i	WP_i	…	$-U_i$	…	$-U_i$	$-U_i$
	public good is realised ⇐			*public good is not realised* ⇐			

To a certain degree, returns now depend upon the number *j* of players other than *i* contributing, because if enough players decided to contribute and public hygiene could be guaranteed, these players would have to pay the maintenance costs.[10] For a particular player *i* the worst case scenario still is the one where he would pay for the maintenance, but many other players would not, so that public hygiene cannot be guaranteed in the end. Thus, the equilibrium reached will be exactly the same as in the simpler two-player case. Free-riding now is possible, and this can enhance peoples' unwillingness to contribute to public hygiene even furthermore, because the own contribution not only is perceived as being useless, there is also an opportunity to get rid of the unpleasant hygienic risks without paying for it.[11]

[9] This assumption is certainly too weak in the case of fire hazard. In fact, a single household not taking care while handling fire was sufficient to cause a devastating town fire (Jankrift 2003: 87).

[10] If not enough players contribute to finally realise the public preventive good, each player will have to write off the equal-share-contribution (TC/n) only.

[11] The result does not change if the game is played in a sequential mode and players no longer have to decide simultaneously. For that reason the outcome can be called a *missing-hero-dilemma* (Diekmann 1992), because on rational grounds no player would decide to contribute, being one of the »heros« who pays for the maintenance of public hygiene. And even if, for whatever reason, enough players had decided to contribute, incentives for the remaining players would not be altered in a way that contribution is encouraged. Quite the reverse,

Describing the situation in medieval towns an open ended repeated game is an even more appropriate model. In general, trust between players can be built up if a game is played repeatedly. A setting with infinite repetitions then can make players opting for cooperation, accepting temporary losses of utility in one round, because with trust the likelihood of being compensated in subsequent rounds is quite high.[12] As long as not all players' contributions are needed to finally realise the public good, there still exist incentives to free-ride, and each free-rider can assume that his own decision will not prevent the production of the public good (Volckart 2004: 28). Mutual trust cannot be effective for another reason here: trust is a powerful tool for the coordination of private interests in small groups (Diekmann 1992), but towns had too many inhabitants for cooperations to be based on trusted relationships only and for effectively preventing free-riding. Hence, as with players assumed to behave rationally a voluntary care for risk avoidance and the provision of public preventive goods such as public hygiene or fire prevention was barely possible, in medieval towns other solutions had to be found to overcome this *public goods dilemma*.

3. Solutions to the problem: institutions to manage collective goods

3.1 The necessity of managing collective goods and the importance of municipalities

Tragedy of the commons and *public goods dilemmata* both demonstrate that property rights and enforcement are of importance when dealing with collective goods. Water supply and the problem of pollution and other communal risks had to be somehow organised to overcome the lack of voluntary contributions to the maintenance of common-pool resources and to risk prevention. For management institutions were needed. Following North's definition (1990: 3) »institutions are the rules of the game in a society or, more formally, are the humanly devised constraints that shape human interaction. In consequence they structure incentives in human exchange, whether political, social, or economic.« Medieval communities developed various institutional arrangements by which collective goods dilemmata could be mitigated. These institutions

while free-riding on the others' investments the last players to decide could benefit from public hygiene already ensured.

[12] In contrast, given a finite number of repetitions and players knowing when the last will be played, cooperation cannot be reached. Players will decide not to contribute in the last round, because no more rounds to be compensated for losses are left. This last-round rationale can be transferred backward to earlier rounds, yielding always the same result (Axelrod 1990: 10; Volckart 2004: 28).

allowed to manage water supply, public hygiene or fire control. A careful exploitation of common-pool resources and the provision of public goods both can be secured by an authority capable of enforcing a cooperation of individuals that is beneficial for the community as a whole. A third party or a collective actor would be such an authority (Greif 2000: 256 f.). In medieval towns cooperation could be enforced by the feudal lord, being at least formally the owner of the town, and by municipal councils which acted on behalf of feudal lords or, in cases where towns had gained a certain degree of political autonomy, on behalf of the community itself. To provide collective goods and prevent misuse of these resources, municipal authorities took care of the management of collective goods themselves, they defined property rights and assigned them to private persons, enhanced voluntary cooperations of inhabitants and tried to regulate environmental behaviour.

3.2. Municipal care of collective goods

As it was needed for commercial activities as well as for personal use and for cleansing, water was the classic common-pool resource in medieval towns. Municipal care mainly targeted the water infrastructure. Canals, aqueducts, cisterns, ditches, gutters and sewers were built to enable energy production by water mills, to provide the water using crafts and allow sewages to be drained off (Guillerme 1988: 51-77, Benoit/Rouillard 2000: 191 f. on France; Magnusson/Squatriti 2000: 227-231, 243-251, on Italy). Sewers were maintained by the community and had to be cleaned on a regular basis, as can be seen from municipal accounts for Paris (Benoit/Rouillard 2000: 203). Another field of municipal investment was the construction of household water supply systems, which had already started in the high Middle Ages. The infrastructure necessary for water supply, a network of pipes, was maintained by the community.[13] These systems were substitutes for the older practice of the inhabitants' provision with water taken from privately owned wells. Paving streets and market places, which helped in keeping the public space tidy, and in German towns for instance became a standard since the late 13th century (Jankrift 2003: 153), was also a subject of municipalisation.

Construction and maintenance of hydrography and the care of other infrastructure devices was an expensive endeavour of course and thus could usually not be made available to the urban population by private initiatives only. If high investments are necessary to produce or maintain collective goods, as a rule of thumb this naturally becomes a public business. Municipalities took over in order to provide these goods and services, a strategy by which the typical public goods problem of non-participation could be solved, in part at least.

[13] See on the distribution of water within town in general Leguay 2002: 173-217; cf. Magnusson/Squatriti 2000: 251, for Orvieto, and Grewe 2000: 145-151, for several German towns (Brunswick, Goslar, Stralsund, Königsberg, Danzig, Freiburg, Nuremberg,Würzburg).

However, financial resources were limited, and with princes in the late Middle Ages often using their towns as financial backers and asking them to reinforce the town's defense system or to build town residences[14], an additional external limit to the budget existed. Especially the maintenance of city walls was quite expensive, and in 14th and 15th centuries these investments which had to be payed by the inhabitants usually were the biggest share of towns' total expenses (Boockmann 1994: 34; Guillerme 1988: 119 f.). As a consequence, finances often allowed to invest either in prestigious and representative projects or in the improvement of public hygiene and the reduction of communal risks.

3.3 Definition and transfer of property rights

Whenever municipalisation was too costly, the supply of collective goods had to be secured in other ways. Such an alternative to a full-range municipal care was defining property rights over common-pool resources and granting rights to use these resources. Numerous examples show that medieval municipalities pursued this strategy quite often. Common-pool resources came under the rule of municipal authorities, and as a result by this claim of property the use of these resources had to be authorised by the municipality and could then be organised under the community's supervision. In Orvieto for instance, the city has granted around 1300 concessions for private pipes which extended the community-maintained water supply system (Magnusson/Squatriti 2000: 251). In 15th century Nuremberg public access to wells was guaranteed whenever they were located on public land, no matter who had financed the construction of the well (Grewe 2000: 148). In Minden and Cologne waste disposal on certain areas and the construction of private sewers had to be authorised by the town council (Jankrift 2003: 179 f.). If a street was too filthy, it was sometimes even closed by municipal order and thus taken away from public use (Jankrift 2003: 160, on 15th century examples from Paderborn and Cologne).

Transferring the rights to use to private persons would be especially useful if investments were too costly for the community or if profits could be made out of the use of a common-pool resource. Examples of a sophisticated high-cost technology are the water supply systems that relied on artificial pumps. Such systems were implemented in several German towns in the late Middle Ages, financed by private consortia. Construction was signed in a contract between investors and towns, and commonly the control over the system was assigned to the main user of the device. In Lübeck this were the brewers, for instance. In Bremen the *Wasserradgesellschaft* that was founded in 1394 of a group of citizens including all town councillors was permitted to build a water wheel at a particular location on the banks of the river Weser (Grewe 2000: 151-153). In

[14] See Ewert 2006: 436-446, on a game theoretical approach to cooperation and conflict between princes and towns during the late Middle Ages.

these examples communities received powerful water supply systems in return for giving property rights away to private persons.

Although property rights were transferred in these cases as well, the management of water mills and public baths was a little different. Medieval towns had quite a long experience regarding the municipal care of all matters related to the provision of inhabitants with grain. Grain storage in public granaries which was useful to smooth price volatility on grain markets, is an example of municipalisation (Ewert/Roehl/Uhrmacher 2007). Water mills were indispensable for grain-grinding. Controlling mills therefore was important for securing the grain provision of the urban population.[15] Medieval towns often owned water mills, but instead of operating the mills themselves, grain-grinding was licensed to a miller in return for a fee. Property rights over a common-pool resource, the mill, were transferred to a holder, which then could charge users of the services produced with this resource and take care about its conservation. The legal basis of running a public bath was quite similar. Since most of the houses did not possess sanitary facilities, public baths were a vital component in maintaining public health, enabling people to keep a certain level of personal hygiene. Visitors could be charged for taking a bath. Although medieval municipalities also owned and operated baths, there were other forms of ownership, for instance investors who had been granted the right to use common waters (Magnusson/Squatriti 2000: 253 f.; Leguay 2002: 236). The common-pool resource »water« was transformed to a club good »bath house«, and public health was converted into personal hygiene. In both cases – the lease of water mills and the authorisation of baths – collective goods could be supplied because property rights were transferred. The municipality was not necessarily operating these resources, but was needed for property rights assignment and for the enforcement of proper use. In addition, pricing was elementary to achieve this, turning collective goods into private ones.

3.4 Enhancement of voluntary cooperation

If the community itself was neither able nor willing to care for collective goods, this gap could also be closed by voluntary cooperations of people concerned. Private initiatives could be fostered by compensating people for the investments they had made in producing a collective good. In Siena those citizens willing to build cisterns and collective wells were offered a payment and free lime in return for their efforts (Magnusson/Squatriti 2000: 244). In Viterbo water was discharged to individual proprietors during exactly specified periods. In return, part time proprietors had to maintain the water supply system (Mag-

[15] Northern German late medieval towns often owned mills, whereas in the South private ownership was more prevalent (Göbel 1993: 41-48). See on milling in Northern France Guillerme 1988: 107-116, on Toulouse Benoit/Rouillard 2000: 192 f., and on Italy Magnusson/Squatriti 2000: 258-265.

nusson/Squatriti 2000: 236). A delegation of responsibility for the supply of a collective good to a group could also be enforced by assigning a formal status to this group. This pattern can be identified with the well collectives (*Brunnengemeinschaften*) that were founded in many German towns from the end of the 13th century onwards. These cooperations being regulated by written rules secured the public supply of water which had relied on private wells before (Grewe 2000: 145). Social networks and formal groups could also function as a non-municipal control to enforce the appropriate use of collective goods, as it was the case with the wool guild in Siena or the butchers' guild in Viterbo which had in their formal statutes regulations concerning the correct use of fountains (Magnusson/Squatriti 2000: 258).

Cooperative solutions that in part were also trust-based can be found in medieval urban history as well. In principle, by reputation and trust people could be enhanced to contribute to the production and preservation of collective goods, but in large communities incentives to free-ride on others' investments were simply too strong. In smaller groups and over time trust worked quite well as a mechanism of coordination, and it seems that by trustworthy relationships at least a basis for voluntary cooperation could be created. For the purpose of preventive fire protection such cooperations were founded. The fire guilds that existed in Northern German towns from the 15th century onwards are such examples. They served mainly as a kind of mutual insurance, compensating for damages and losses due to fire, but also were the basis for organising fire protection more systematically (Grewe 1991: 71). In all examples mentioned in this section a collective good was transformed into a club good, an efficient strategy to enhance voluntary contribution as well as preservation.

3.5 Regulations and the demand for personal responsibility

By municipalisation, transfer of property rights and enhancement of voluntary cooperations it was possible for medieval communities to mitigate the supply problem of a quality-of-life-related collective good such as water. Achieving preservation of this good and of other collectively used infrastructure was even harder. As the maintenance of the systems remained under the supervision of the community, they were often managed rather poorly due to budget restrictions and thus are typical examples of common-pool resources to be constantly degraded. In Italian towns taking water from civic water supply devices like wells and fountains was often free of charge (Magnusson/Squatriti 2000: 241). In connection with water supply typically free-riding evolved. French royal decrees of the 15th century recurrently mentioned private derivations of water from an aqueduct in Paris, namely by members of the high nobility (Benoit/Rouillard 2000: 200). Prohibitions of waste disposal in common waters are numerous, showing that pollution was a serious and quite notorious problem (Benoit/Rouillard 2000: 203; Leguay 2002: 120, 124; Magnusson/Squatriti

2000: 253, 256). In Northwestern German towns municipal responsibility of cleaning the pavement can be observed not until the late 15th century (Jankrift 2003: 153 f.). A similar rule applies to fire prevention which was poorly organised even in the late Middle Ages. In the 15th century regulations concerning fire fighting can be found[16], but in many German towns the municipal organisation of fire fighting was commonly confined to reimburse private persons for their efforts made while fighting a fire and to employ people who's duty it was to warn of fire (Grewe 1991: 71, on Cologne and Lübeck; Jankrift 2003: 92-98, on Munich).

Enforcement of people to refrain from deteriorating common-pool resources and to contribute to the prevention of risks can also be exercised by command or moral appeals. This becomes clear when looking upon the incentive structure of the *public goods dilemma*. To enhance contribution incentives have to be changed. A powerful collective actor can either order individuals to choose the contribution strategy or try to convince them doing so, hoping that people will feel responsible for the common property. With respect to public hygiene and fire prevention these instruments appeared quite frequently in medieval towns. First regulations concerning pollution and public hygiene were issued in Italian and French cities in the 13th century, mainly calling for cleanness and sanitation and aiming at regulating the disposal of organic waste materials into waters and streets (Balestracci 1998; Leguay 2002: 136 f., on Avignon; Magnusson/Squatriti 2000: 253 f., 256 f., on Milano, Ferrara and Verona). This kind of strategy to improve sanitation and risk awareness was imitated by municipalities elsewhere in Europe during the late Middle Ages. Already the *Sachsenspiegel*, the earliest and by far most influential German law book that dates back to the first half of the 13th century and of which regulations were copied into many German municipal laws, contained rules concerning public hygiene and fire prevention. Toilets had to be put into a shelter of bricks that was extended to the ground to protect neighbouring areas from excrements and stench. Ovens had to be covered such that sparks could not cause a fire hazard for the house itself as well as for other houses (Oldenburger Sachsenspiegel 2006: fol. 56v-57r). In Northwestern German towns disposal of waste and sewage had to be carried out by the households themselves. Usually, the towns' municipal councils would intervene only if public interest was severely endangered. Thus, draining off sewage often caused disputes between inhabitants, and the town council then was needed as a referee to settle such conflicts (Jankrift 2003: 177-180). Other regulations can be found regarding fire control. In Cologne and Munich for instance, in 14th and 15th centuries people were requested to have fire fighting devices like ladders, buckets or crooks at hand. Furthermore, to minimise the risk of a fire to spread, the houses' roofs had to be tiled with tiles instead of thatches or wooden materials.

[16] Such regulations were issued in many important Europaen cities, for instance London in late 12th century, Bruges in 1232 or Lübeck in 1276 (Jankrift 2003: 91).

Appeals did not succeed as the situation of public hygiene did not improve significantly, and fire prevention was not sufficiently well organised either. This was because of two reasons: firstly, enforcement was inadequate. Coming back to the public goods realisation game, a fine equal or greater than the share of contribution *TC/n* to the provision of a public preventive good would have been enough to change the incentive structure such that contributing would have become a utility maximising choice. Although in principle violating regulations was punished[17], due to lacking monitoring opportunities municipal authorities seemingly were not capable of rigorously enforcing these regulations. A key element for this kind of enforcement to succeed is that individuals face a high likelihood of being detected in case of offending against rules (Volckart 2004: 28). This was usually not the case with waste disposal in medieval towns, and interestingly enough, town officials in Wesel tried to improve the hygienic moral of inhabitants at the end of the 14th century by letting controllers watch over the cleanness of streets and granting them the right to take half of the fines imposed on polluters (Jankrift 2003: 159). Secondly, as has been shown in environmental sociology, people are willing to contribute to the preservation of the environment as long as the requested activities are cheap for them.[18] In the medieval urban case the usual demands for personal responsibility to reduce and prevent communal risks were not of a low-cost character for inhabitants at all. As buying fire fighting devices or making roofs fire-proof was costly, and as also the disposal of waste would have been expensive, if it was not done by burying the waste in the backyard of houses or throwing it directly onto the street, people instead faced a high-cost situation, which made voluntary contribution to a cleaner environment rather unlikely.

[17] Fines were a common practice, for instance if, as it was the case in Lübeck, fire ordinances were offended against (Grewe 1991: 71). In the example of the water supply system in Bremen customers who had manipulated the pipe and had attempted to take more water than allowed to were punished by demolition of their water tank (Grewe 2000: 157). In Italian cities a punishment for the misuse of fountains was sometimes also the banishment from town (Magnusson/Squatriti 2000: 257).

[18] Low-cost and high-cost situations for decision are distinguished with respect to the costs individuals would have to contribute to the preservation of the environment (Diekmann/Preisendörfer 1998: 240 f.).

4. Development over time: too poor to be risk aware?

4.1 I-PAT-identity and Environmental Kuznets Curve: accounting for the impact of population and wealth on the emergence of negative externalities

In medieval towns degradation of common-pool resources was confronted with regulations. Are changes over time observed both in the emergence of negative externalities and in peoples' attitudes towards pollution and the treatment of other risks? The classic view of the medieval city as having been a crowded, polluted and unhealthy place is somewhat inaccurate, because this image seemingly catches the environmental and hygienic situation of the later Middle Ages only (Guillerme 1988: 116). Assuming a fundamental change in the living conditions of urban dwellers means to look upon potential factors driving this change, namely population growth, population density and an increasing wealth in towns.

Demography and environmental economics have developed tools to study the correlation of population, income and environmental effects (Cropper/Griffiths 1994). A quite popular concept to assess the population impact on the environment is the *I-PAT*-approach (Ehrlich/Holdren 1971). An environmental impact *I*, which is the degree of pollution, is related to population size *P*, the level of affluence *A* and the environmental features of the production technology *T* that is in use. Affluence is given as per capita income and technology is measured in terms of pollution per unit income. Applying the mathematical identity displayed below, the total amount of pollution can be decomposed into factors, allowing to distinguish population, income and technology effects.[19]

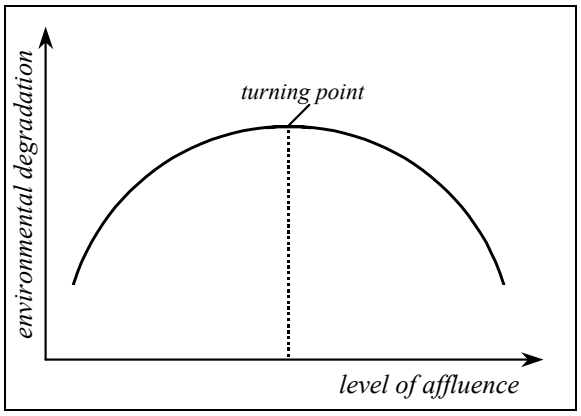
$$I = Population \times \underbrace{\frac{Income}{Population}}_{Affluence} \times \underbrace{\frac{Pollution}{Income}}_{Technology}$$

As can be seen from the *I-PAT*-identity, negative environmental externalities will increase in intensity as the population is growing and becoming richer. More people will *ceteris paribus* increase the total amount of pollution.

[19] Using growth rates instead of levels and taking logarithms, an increase in pollution can be written as a linear function of population growth, per capita income growth and improvements in technology: $ln(I_t/I_0) = ln(P_t/P_0) + ln(A_t/A_0) + ln(T_t/T_0)$.

Technology is a scaling factor by which the degree of pollution can either be dipped or lifted, and a higher level of income is assumed to induce technological progress which then helps to relax the strain that is put on the environment by a growing population. In the *Environmental Kuznets Curve* (EKC) the potential relationship between environmental degradation and wealth is specified more precisely. This concept is based upon the empirical regularity of an inverted U-shaped function displaying the correlation between these variables. In many studies on pollution this type of functional relation was found (Andreoni/Levinson 2001; Hill/Magnani 2002; Levinson 2002; Yandle et al. 2004; Deacon/Norman 2006). Quite similar to the *I-PAT*-identity the impact of human activity on the physical environment at first becomes more detrimental with the income rising, but after the threshold of a certain level of affluence is passed, pollution will be reduced and environmental degradation begins to cease although income increases furthermore. The term *EKC* was coined with reminiscence to the *Kuznets curve* (Selden/Song 1994), proposed by Kuznets and saying that throughout economic development per capita income and income inequality are related to each other with an inverted U-shaped function (Kuznets 1955; van Zanden 1995).

Figure 1: A schematic sketch of an Environmental Kuznets Curve



Although suffering from theoretical and empirical problems, this concept is intuitively appealing.[20] From a theoretical point of view it is somewhat imprecise, because distinct explanations are given for the relationship of affluence

[20] An empirical problem arises if several cases (towns, regions or states) are studied in a cross-section. The U-shaped sketch then is found mainly because cases are in different stages of economic development, and not because environmental degradation for a particular case necessarily changes over time with the population's per capita income rising (Deacon/Norman 2006).

and pollution to be inverted U-shaped. A possible reason for the upper tail to decrease is that environmental quality can be seen as a component of the quality of life which is appreciated only after a certain level of affluence has been attained and basic needs are satisfied (psychological explanation). The decrease alternatively is interpreted as the effect of pricing environmental hazards that had not been priced before (micro-economics explanation, Yandle et al. 2004: 6), as a result of economies of scale that evolve in controlling pollution and negative external effects (organisational explanation, Andreoni/Levinson 2001), as a consequence of the definition of property rights over common-pool resources and the implementation of regulations to prevent negative externalities (institutional explanation), and finally as the effect of technological progress improving technology to the benefit of the environment (technological explanation). Unfortunately, the concepts of *I-PAT* and *EKC* cannot be used for empirical studies here, because the amount of pollution or the degree of risk in medieval towns can hardly be quantified. If the *EKC*-paradigm is generalised to an inverted U-shaped relationship between income and communal risks, the different explanations are a useful pattern for a more general interpretation of factors determining both emergence and treatment of such risks in medieval towns.

4.2 Population growth and economic development as driving forces of environmental degradation and communal risks

Tracing back environmental degradation to population growth and increasing wealth, as suggested in the *I-PAT*-identity, gives some hints whether there was a kind of general pattern in the emergence of environmental hazards in medieval towns over time. Population growth certainly was a key element, because in the high Middle Ages population grew rapidly, but in the newly founded towns and cities population pressure still was relatively low, and therefore degradation of the physical environment seems to have happened at a quite moderate level only (Guillerme 1988: 116). Milling statistics for northern France confirm the rapid population growth, showing that the number of mills in towns rose significantly during this period (Guillerme 1988: 82-93). Numerous regulations by feudal lords or municipal councils then started to appear in the 13th century when population growth peaked. The deep concern about environmental hazards that shines through these initiatives indicates that population pressure in towns had increased to a level at which the environmental component of the quality of life was seriously threatened (Magnusson/Squatriti 2000: 256).[21] Population density in cities usually was in the order of 100 inhabitants per

[21] If an individual produced about 150 grammes excrements and 1-1,5 litres urine per day, a town of 5,000 inhabitants would have had to dispose ca. 275 metric tons excrements and 3,000 metric tons urine per year (Leguay 2002: 123).

hectare at least, but in many places exceeded this value.[22] It was at this point in urban history, that towns not even expanded their settled area significantly, but seemed to have also used expansion for a fundamental topographical reorganisation, moving the polluting and hazardous crafts and other sources of hygienic risk like hospitals to the towns' outskirts in the newly settled suburbs (Leguay 2002: 138).[23] In the late Middle Ages, population pressure in many towns remained high. At first glance, this may seem kind of paradoxical, but in fact it was not, because although with Black Death population losses of towns had been higher than in rural areas (Rahe 1984: 128 f.), the urban-rural differential in terms of income increased even more in the aftermath of this crisis, making towns still the favoured destination for migrants. Being confined to the already settled area, the majority of inhabitants concentrated in the older core areas of towns, keeping population density still quite high.[24] As a matter of fact, environmental degradation and the difficulties for civic life related to it consequently were not really decreasing.

Assuming that wealth in towns had increased throughout the 12th and 13th centuries, at the same time when urban population was growing rapidly, seems quite reasonable. With the rise of long-distance trade in the so-called *commercial revolution* (Lopez 1998), all across Europe towns developed into mercantile centres, the Italian port cities, the Flemish urban network and the Hanseatic cities being the most prominent examples (Ennen 1987: 155-206). Was it income rather than population growth that had stimulated the increase in environmental degradation and the depletion of common-pool resources? As population growth and the increase in wealth are highly correlated, this hypothesis cannot be tested empirically. There is a good reason at least why income could not have exerted the main impact on the sheer amount of pollution. Environmental degradation in medieval towns resulted from polluting production methods and a hazardous behaviour regarding matters of daily life. None of these sources significantly changed over time. In contrast to modern western economies where for instance the rising level of affluence after World War II stimulated people to rely on ever more fuel-consuming and air polluting modes of traffic, the amount of swill and organic materials as the primary sources of pollution in medieval towns certainly was not increasing only because people

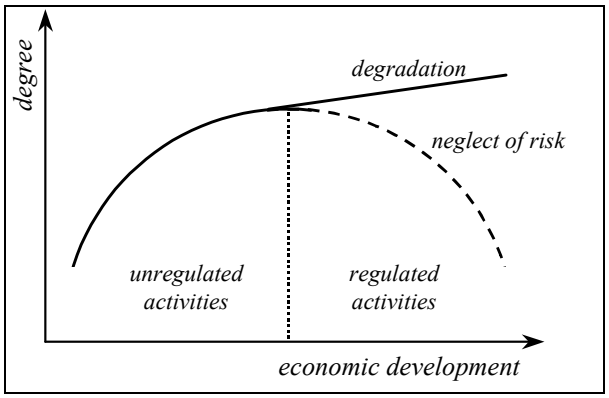
[22] Population density of several cities in 13th and early 14th centuries is reported in Ennen 1987, 228 (Ghent 100 inhabitants per hectare; Toulouse 100; Nuremberg 142; Wismar 150; Rostock 158; Paris 180; Lübeck 210; Béziers 322; Genoa 545).

[23] For Northern French towns it can nevertheless be shown, that in the time before artisans' activities were topographically arranged such that pollutants from different crafts were neutralised and helped to refresh and to purify the water again. By destroying this arrangement, for instance by moving abatoirs downstream the town, the problem of pollution and hygienic risk was not solved, it even got worse (Guillerme 1988: 99 f.)

[24] In 14th-15th centuries population density of Northwestern German towns was about 100 inhabitants per hectare (Cologne 100; Aachen 86-114; Münster 98; Dortmund 86-123; Duisburg 91; Essen 81; Soest 119). This value appears to have been quite typical for other German regions. (Jankrift 2003: 149 f.).

became wealthier. Is the concept of *EKC* therefore inappropriate for approaching the occurrence of negative externalities in medieval towns? That environmental hazards were significantly reduced in the later Middle Ages can be doubted, at least. The recurrent appeals, regulations and orders of authorities do point to the fact, that the environmental problems caused by certain daily life practices obviously had not been satisfyingly solved.[25] Correlating emergence and degree of risks with income would thus not prove a decreasing upper tail of the functional sketch. Although municipal authorities had started to tackle the problem, the intensity of environmental degradation remained constant, at best, but probably even increased furthermore (see Figure 2).

Figure 2: Potential sketches of the Environmental Kuznets Curve for medieval towns



The late Middle Ages marked a change in peoples' attitudes towards pollution insofar as the hygienic problem was recognised and also confronted. Although urban health conditions did not improve significantly until the 19th century, a turn regarding the awareness of communal risks can be observed. Being more regulated with regard to hygienic matters life in the economically and politically more developed late medieval urban communities was different from the life before, this having been subject to only a few of such rules. Once this turning point was passed, not the risk itself ceased, but hygienic hazards were seriously perceived as such and no longer neglected. The concept of *EKC* thus can be used to illustrate the issue of pollution, hygienic risks and preserving strategies in medieval urban communities, if these aspects are correlated with economic and political development instead of income only. In many towns during the late Middle Ages economic development promoted a rising

[25] This pattern then continued well into early modern times. See on the situation in Northwestern German towns Jankrift 2003: 154-167, and on that in Saxon and Silesian towns Schlenkrich 2005: 58-60.

disparity of income (Ennen 1987: 241-246).[26] Speaking in economic terms, they were on the increasing lower tail of the original *Kuznets Curve* that relates income with income inequality (van Zanden 1995: 643 f.). A higher income differential within the town population meant that the majority of inhabitants simply was too poor to be aware of the hygienic hazard they caused with their behaviour and to reduce or avoid this risk. A minority of citizens in turn was already rich enough to develop aspirations for a life free from hygienic hazard and other communal risks. As these upper class members dominated urban politics due to their wealth and social prestige, they were able to develop an agenda concerning the issue of public hygiene. The term »pollution«, not known in the high Middle Ages, started to appear in sources of the 13th century (Leguay 2002: 117, 119). Feudal lords and municipal authorities were eager to keep their towns tidy and clean, for hygienic as well as for aesthetical reasons (Leguay 2002: 163 f.). Italian cities obviously became aware of environmental hazards earlier than communities elsewhere in Europe. This early appearance of measures taken against pollution likely was not only due to the immense population figures of these communities, but also to the quite advanced economic and political standards they already had reached in 13th century. In contrast, for Northwestern German towns similar attempts of municipal authorities can be observed not before the 14th and 15th centuries (Jankrift 2003: 151-166). Towns like Soest or even Cologne were important trade centres, but certainly lacked the economic standard of Italian cities. Moreover, economic development enabled investments in technology to improve the hygienic situation as can be seen with the construction of new water supply systems in the late Middle Ages. This became possible because wealth had increased, so that in principle expenses related to such endeavours could be afforded. If public budgets were short, there were at least enough wealthy citizens who could be enhanced to sponsor such devices. Besides the effect of economic development there was finally of course also the exogenous factor of plague. Black Death and the recurrent outbreaks of plague thereafter were important inasmuch as it intuitively became clear to contemporaries that an insufficient public hygiene very likely was to foster the spread of infectious diseases.[27] This certainly was a major step towards a civic life that was regulated also with respect to public hygiene.

[26] In Florence and Pistoia (1427), Freiburg (1445), Haarlem (1483), Dresden (1488) or Leiden (1498) for instance *Gini-coefficients* were in the order of 0.75, indicating a quite high degree of income inequality (van Zanden 1995: 645 f.).

[27] The connection of public hygiene and infectious diseases was not completely understood in the 14th century indeed, and concerns were particularly focussed on air as being the potential transmitting medium of infections (Bulst 1979: 59; Rahe 1984: 130; Schlenkrich 2005: 57 f.).

5. Conclusions

Daily life in medieval towns was shaped by the inhabitants' environmentally harmful way of life. To ensure minimal standards of the quality of life, the communal risks coming with these negative externalities – hygienic problems and fire hazard – had to be minimised to the highest degree possible. As a consequence of water, public hygiene and fire control being collective goods to the community, all the difficulties supposed to arise with respect to such goods – refraining from participation, free-riding, a need for property rights definition and third-party-enforcement – can be observed in medieval towns. Assuming rational behaviour of individuals, quite naturally common-pool resources like waters and streets were over-exploited through polluting them, and individuals faced no incentive to deliberately contribute to a reduction or avoidance of the resulting communal risks. Urban history shows that medieval communities nevertheless tried to overcome this collective goods problem. By municipalisation, assignment of property rights, enhancement of voluntary cooperations and regulations it was possible to provide citizens with common-pool resources, but environmental quality could only be slightly improved.

Three points in particular are to be highlighted here. Firstly, negative environmental externalities and, more generally, communal risks appear to have emerged indeed more often with wealth of medieval towns increasing over time. So did the awareness of these hazards as well as a fundamental understanding to handle the difficulties related to them. This notwithstanding, the driving force behind this was population growth and the resulting sharp increase in population density. In the crowded late medieval towns an environmentally harmful way of life caused many more problems than it has been the case in the less densely populated towns of the high Middle Ages. Moreover, although municipal administrations increasingly attempted to regulate environmental behaviour, a clear tendency towards a significant reduction of negative externalities as suggested by the *EKC*-paradigm cannot be detected. Risk-wise, medieval urban communities in a sense became victims of the economic power they had gained, making them an attractive destination for migrants. Secondly, common-pool resources became a subject of regulation by a central authority whenever this promised to be a profitable endeavour. Water milling and grain grinding are good examples for this rule. Running such enterprises or capitalising their property rights over these resources also shows that feudal lords and municipalities orientated themselves to economic gains and therefore took economically rational decisions. In contrast, waste disposal and cleanness of streets were tried to regulate only at a point in time when taking care for it no longer was avoidable because of the massive risks resulting from the misuse. Finally, facing communal risks and managing collective goods for the members of municipal councils was a matter of balancing the town's economic interests with the conflicting interests of certain community members and the

necessity to improve the quality of life for all inhabitants. If municipal councils reacted rather inefficiently to the omnipresent hazards, it presumably happened also because in this trade-off fulfilling economic interests and settling internal conflicts usually had a higher priority than improving the quality of life.[28] Moreover, very similar to today's considerations, the call for a personal responsibility concerning preventive means was also guided by budget restrictions.

Whenever theoretical concepts are used to analyse historical institutions, the question arises whether this sort of approach can help explaining historical phenomena. Is it useful to analyse community policies of medieval towns within a rational-choice setting, thereby assuming individuals having tried to find solutions by which they could have attained a higher personal utility level? Rational-choice and game theory cannot explain historical details indeed, but these concepts allow to put the institutional arrangements of the past within a systematic framework. On the one hand side, the specific way in which medieval communities handled communal risks and quality-of-life-securing collective goods does underline that the margin for political action in medieval society was different compared to modern society. On the other hand, the rational design of means implemented to make common-pool resources available, to prevent over-exploitation and to reduce communal risks proves very well that assuming rational choices with regard to the management of these problems is reasonable and can be justified on empirical grounds even in medieval urban communities. People in the Middle Ages not only were aware of the detrimental impact their way of life had on the physical environment and on civic life, they also found solutions to this challenge, although some of the institutional arrangements may not have been completely efficient. Hence, medieval urban history lends itself to the illustration of problems emerging for communities from the use of common-pool resources and from dealing with communal hazards to improve the quality of life, and it can also be used as a test providing historical evidence of whether theoretical concepts discussed in environmental economics are empirically valid.

[28] Generating price stability on the grain market for instance was usually done with a clear aim to prevent upheaval which in turn could have threatened the political influence of the members of municipal councils, not primarily to improve the inhabitants' quality of life (Persson 1999: 75). Such a behaviour was rent seeking insofar as social élites used municipal institutions to serve their private interests. See on the application of rent seeking to medieval urban policy Lehmann 2004.

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