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Un-Vignetting vignettes: Optimal highway pricing in Croatia

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ABSTRACT

In the art of photography, the phenomenon of vignetting means blurring of an image at its periphery compared to its centre. Vignettes are a form of road pricing independent of travel distance. Their usage in Croatia was recently rejected while in Europe, the number of countries using them, is increasing. The economic question of using vignettes as a primary source of revenue for the financing of Croatian highways was blurred by economically peripheral but politically sensitive welfare transfer issues. There has been no visible attempt to push the discussion back into the field of economics by using purely economic criteria such as: opportunity cost of usage, "sunk costs", marginal costs, and total costs recovery. The paper aims at un-vignetting (un-blurring) the issue and re-focusing it towards economic arguments. The approach taken is a deductive-nomological argument based on opportunity costs of usage. The conclusion is straightforward: the vignettes are Pareto efficient since they make the society in general and the consumers in particular ultimately better off even after taking into account compensations. The opportunity costs of usage of congestion-free roads are zero. The optimal quantity-dependent price is then also zero. Since zero price does not recover costs, a differential pricing scheme needs to be put in place: one that does not depend on distance travelled.

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1 Introduction

In the art of photography, the phenomenon of vignetting means blurring of an image at its periphery compared to its centre. The centre is in focus, whereas the periphery is not. In the science of transportation economics and public finance, vignettes are a form of road pricing independent of travel distance. Vignettes are used for pricing car travel in Austria, Bulgaria, Czech Republic, Hungary, Italy, Moldova, Romania, Slovakia, Slovenia, Switzerland, their introduction is under way in Germany, and their use was considered for Croatia, but recently rejected. Vignettes are a form of quantity independent pricing used to recover the "sunk costs" of road construction in the case of a supply of a typical "club good" where there are no positive opportunity costs of road usage.

Why does the question of vignettes need a substantial un-vignetting or un-blurring in Croatia? The question of vignettes is blurred by irrelevant political arguments and discussions that have entirely taken-over the decision-making process, and the discussion has been entirely stripped of any economic arguments. Even as the question of vignettes was revisited due to fiscal problems, the main economic argument in favour of vignettes was neither pointed out by the advocates nor was criticised by its opponents.

The main economic argument in favour of vignettes is quite straightforward: the opportunity costs of highway usage by cars is zero until the point of congestion.

Congestion itself may be created by suboptimal allocation (pricing) mechanisms. For example, the toll booths at exit points may create congestion problems. Contrary to cars, the opportunity cost of highway usage by lorries (trucks) is positive as significant road depletion costs as a function of road use imposes positive marginal costs of reconstruction (replacement). So, the pricing of roads and highways for the purposes of lorry transportation is out of the scope of this paper, and a separate European Union proposal for its pricing is already under examination by the member states. This paper focuses only on the eco-

nomic theory behind various road pricing regimes for cars and their optimality.

The question of vignettes in Croatia needs to be refocused to an economic analysis, and especially an economic one based on static and dynamic social efficiency and Pareto optimality, on the commensurateness of underlying mechanism designs with Pareto optimality, on the recoverability of infrastructure investment costs bearing in mind the opportunity costs of road usage; on economic consequences and adherence to the user pays normative principle, and finally, the necessary application of some compensation criterion during the transition phase and the resulting ethical issues.

There are two aspects of efficiency: the microeconomic one, considering only the accounting expenses and revenues of the highway system as a self sufficient enterprise and the macroeconomic one, taking into account the overall social effects of its spill-overs. The general economic criterion is given by the fulfilment of marginal conditions necessary for Pareto optimality. When opportunity costs of infrastructure usage are nil, the Pareto optimal price is also nil. But such a pricing scheme obviously does not recover initial investment costs that are sunk and if the highway were a private enterprise, such a pricing scheme would quickly push the enterprise into bankruptcy. Any private provision of highways would then need a pricing scheme with revenue (profit) maximisation as an objective function. The private sector has successfully managed to develop similar pricing schemes in telecommunications and broadcasting where the price is not related to the quantity but to the usage time instead. Why is the governmental sector unable to develop its own organisational mechanism designs that would allocate the good efficiently and serve the public interest at its best? One of the possible answers is certainly political: political elites serve their own political interests and are prone to log-rolling and pork-barrel policies.

Nevertheless, such an argument is deficient as the conclusion does not follow from the premises. Economically efficient systems create additional value that may be redistributed among voters. Thus, if vignettes are economically more efficient, the economic losers may well be compensated by economic gainers making the society overall better off. As it may be noticed, at least these four issues need to be discussed:

1. optimal infrastructure quantity,
2. optimal infrastructure operational organisation,
3. optimal and efficient pricing, and
4. equity of welfare redistribution.

The paper is organised into three additional chapters: the following chapter gives a short theoretical and literature review. The third chapter giving theoretical arguments and fourth chapter giving organisational aspects of the issue. The fifth chapter concludes the discussion.

The paper does not aim at giving a definitive conclusion to the topic but calls for further discussion and analysis.

2 Theory and literature review

The literature on the general problem of public goods and infrastructure is immense and if we don't take into account Adam Smith's *The Wealth of Nations*, it starts in principle with the German economist Schäffle [23] that argued that the state is more efficient than the market in the case of goods that serve many people at once. Wagner's *Foundations of Economic Policy* puts forward the defining criteria of joint consumption (non-rivalry), and non-excludability [28]. He defines non-rival goods as being able to service additional consumers at low or zero marginal costs [28]. This work on the basic division of goods into private and collective consumption goods, shown in Table 1, the distributional difficulties with the revenue-expenditure process in the public sector, as well as the nature of the pricing process itself, was explained by Musgrave [17, 18].

Table 1 Classification of goods according to rivalry in consumption and excludability from consumption

		Excludability from consumption	
		Excludable	**Non excludable**
Rivalry in consumption	**Rival**	Pure private goods	Common goods
	Non rival	Club goods	Pure public goods

Source: Mance et al. (2015), p. 127.

The basic idea of a collective consumption good was taken over and laid down in a mathematically rigorous way by Samuelson [22]. The consequences are shown graphically in Figure 1 as a movement from an inefficient state to an efficient state on the Pareto frontier.

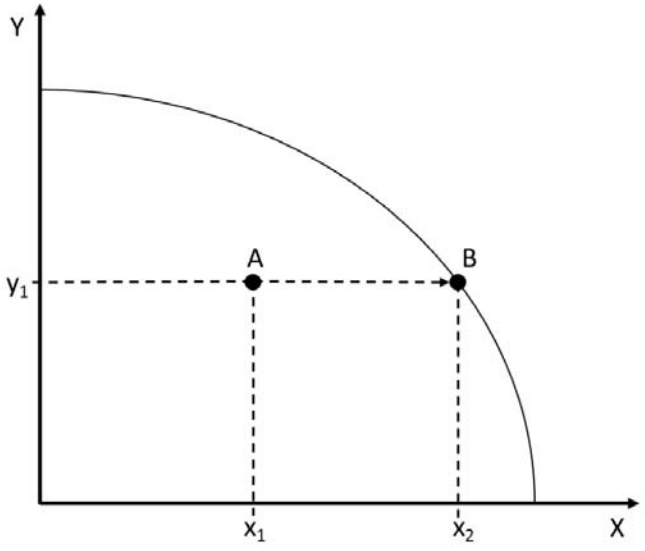

Figure 1 Pareto optimality frontier with private and collective consumption goods

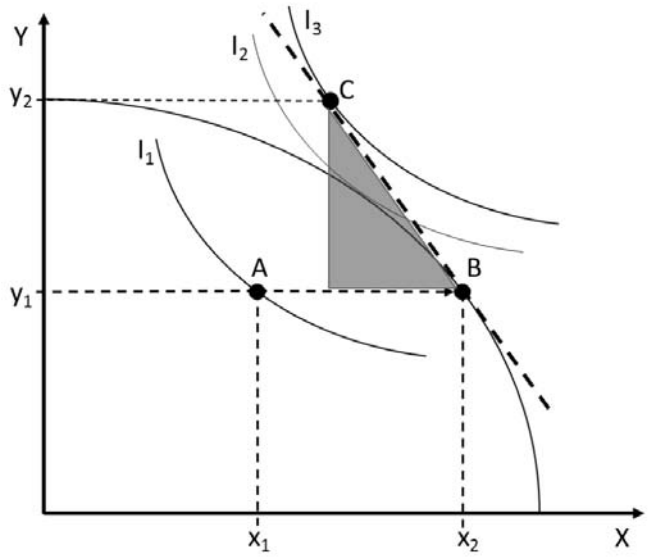

Figure 2 Extension of the Pareto optimality frontier with maximum usage of the collective consumption good and trade

In an economy consisting of two goods: the collective consumption good X and the private consumption good Y, the increased consumption of the collective consumption good X from x_1 to x_2 increases the social welfare from point A to point B. The basic idea consists of moving the actual production and consumption to the Pareto frontier by maximising the use of available resources.

In his *The Economics of welfare* Pigou puts forth the idea that, *ceteris paribus*, higher outputs increase welfare [20]. By increasing the consumption of the collective consumption good, both welfare and the national income increase as the collective consumption good (roads and highways) is both a final consumption good as well as a resource for the production of tradeable goods. This hypothetic expansion of the production possibility frontier is shown on the right in Figure 2.

For the entire economic argument of zero opportunity cost of usage, we need to be bear in mind the fact that there is only an absence of the opportunity cost of usage, and not an a priori absence of opportunity costs of production. As a matter of fact, and as shown in Table 2, the opportunity costs of production are positive, as before construction they amount to the value of the real option on total investment from the societal point of view. The value of the real option on the investment for a profit seeking investor might be different. When the option is exercised, the real option looses its value and the entire cost is irrevocably sunk. Until the point of exercise, we may talk about the *prospective sunk cost* being a positive production cost that needs to be recovered. A thorough representation of types of goods and markets developed during more than 50 years of discussion by Musgrave [17, 18], Samuelson [22], Buchanan [4, 5, 6, 7], and ultimately Ostrom [19] is given by Mance et al. [16].

A clear cut conclusion of the efficient pricing problem at marginal cost in industries exhibiting increasing returns to scale and large fixed ("sunk") costs, was given by Varian: "The appropriate guiding principle in these contexts should be that the marginal willingness to pay should be equal to marginal cost. This condition for efficiency can be approximated using differential pricing, and will in fact, be a natural outcome of profit-seeking behaviour." [26] Needless to say, the primary function of government is not to make profits, but to provide for necessary public goods that would increase social welfare.

Table 2 shows the relationship between opportunity costs of production and opportunity costs in consumption as determinants of the types of goods.

By increasing the consumption of the collective consumption resource X, a country is able to increase its welfare firstly from point A to point B, and afterwards by using some of the collective consumption resource X to produce a tradeable good that would be traded for the private good Y. In this way, an even higher indifference curve I_3 might be reached. The theory is clear about the benefits of vignettes as a pricing mechanism of a non-scarce good from the moment it has been produced.

The problems with highways arise when congestion happens. Congestion is a consequence of road speed differences due to lacking capacities of connected arterial roads, traffic accidents, etc. When a highway segment cannot be cleared by connecting roads, congestion follows. This is mostly the case during rush hours when the number of cars entering key road sections is much larger than the connected roads are capable of clearing. "It should never be forgotten that the highway problem is essentially one of peak load. There is little traffic congestion, even in Manhattan, at three in the morning." [5] Now, the problem of peak traffic load in Croatia is not one between

Table 2 Opportunity costs of production and opportunity costs in consumption

		Opportunity costs of production	
		Positive prospective sunk costs = positive real option values	**No prospective sunk costs = non positive real option values**
Opportunity costs in consumption	Positive MC in consumption	Private and lumpy goods $MC_x \approx P_x$; $P_x > 0$; $PSC > 0$	Common goods $MC_x > P_x$; $P_x = 0$; $PSC = 0$
	No MC in consumption	Monopoly goods $MC_x = 0$; $P_x > 0$; $PSC > 0$	Non economic goods $MC_x = P_x = PSC = 0$

Source: Mance et al. (2015), p. 127.

morning and evening rush hours, although these also happen in larger cities, but one between winter and summer seasons. During summer, Croatia's population nearly doubles, and there are some issues with congestion, although most of it happens at highway entrances and exits for the purpose of payment at the toll booths. Differential pricing is not a long term solution for the problem of congestion, although differential pricing is a good short-term economic allocation mechanism. There are no solutions in economics: there are only trade-offs. The long term solution may only be of technical nature: an infrastructure capacity increase.

3 Cost structure and revenue management

The theory behind a vignette is quite straightforward. A road or a highway is a form of communication and transportation infrastructure with extremely high fixed costs that are entirely "sunk" at the point of investment. Once a cost is "sunk", from an opportunity cost perspective, it becomes irrelevant for business decision-making [2, 3]. Extremely high "sunk costs" are a primary reason why roads and highways are either governmentally financed, or part of a concession agreement between government and road operator as irreversible "sunk costs" pose a source of bankruptcy risk for the provider [16]. Concession agreements are governmental warranties to the provider that risky "sunk costs" of the investment are not in any form to be expropriated by the government, and a further warranty against undue competition, thus creating a governmentally protected monopoly, although, this second aspect is important only to a lesser degree since large "sunk costs" of the investment are themselves a *barrier to entry* to competitors creating a natural monopoly. Let us remember that natural monopolies are created by specific cost structures that make it unprofitable for the potential competitors to enter the incumbent's market if the marginal cost of operation is lower than the average variable cost, and when the total quantity demanded by the market is lower than the total capacity provided by the monopolist. Specific cost structures create specific incentives, and specific conduct by the incumbent firm, that results in a specific performance. Structure-conduct-performance analysis of natural monopolies is beyond the scope of this paper. The second important aspect of the road cost structure is the almost inexistent marginal cost of usage until the point of congestion. By inexistent opportunity cost of usage it is meant the cost of providing an additional consumption unit of a good or service at zero cost. This point is a critical one in understanding the advantages of vignettes over other allocation and finance mechanisms.

3.1 Efficient pricing theory

According to the efficient pricing theory an outcome is Pareto efficient if no consumer can be made better off without making some other consumer worse off. A necessary condition for Pareto efficiency is that the marginal willingness to pay equals marginal cost. Marginal willingness to pay means willingness to pay for an additional unit of the good. Marginal cost means the cost of an additional unit of the good. Since both marginal willingness to pay, and marginal cost amount to zero (or near zero), quantity dependent price needs to be zero to have a Pareto efficient outcome. [26]

Marginal cost and marginal price refer to additional consumption units and not to overall costs and overall prices paid for the service. This means that the last consumption unit needs to have zero price. It doesn't mean that the overall price across the demand curve should be zero. Thus, price discrimination of second degree, and possibly some sort of price discrimination of third degree would comply with this requirement. Any form of pricing that is separate from the consumed quantity does not contradict the efficient marginal pricing rule. The problem to be solved may be represented as one of revenue management optimisation according to price discrimination policies and having regard to following constraints: full recuperation of infrastructure building costs, and maximisation of domestic social utility of road usage without discriminating other EU nationals. An additional ethical rule might be added: adherence to the "user pays" principle as much as applicable under the circumstances, although the norm has no backing in positive economics in case of non-scarcity.

The optimal solution to the problem is probably a corner solution to the linear programming model with the goal function of social utility maximisation under constraints of cost recuperation and if applicable profit maximisation with the price mechanism designed not to discriminate by EU nationality. The solution is then either vignettes having an average price equal to the amount needed to recuperate costs divided by the total expected number of vehicles using the highway system during the observed period. All other vignettes would then be priced around this benchmark average. If price discrimination is to be effective, market segments need to be identifiable by their demand price elasticity, and the scheme needs to pass the EU Commission test for non-discrimination.

There is nothing special about pricing of highway usage that wasn't already seen in other markets such as telecommunications. There is a multitude of available packages from telecoms: time defined flat-rate packages, pay-per-minute, pay-per-second, pre-paid packages, loyalty programmes, and every possible bundling combination thereof. Highway pricing will need to price discriminate to increase revenues and social welfare.

Vignettes are a quantity based price discrimination mechanism as shown in Figure 3.

In case of regular congestion times, a highway with governmentally regulated prices of vignettes, may in addition develop a time-based, peak load, dynamic pricing based on opportunity costs of usage and an estimate of the price elasticity of demand. The more elastic the demand, the more revenue is collected with more quantity

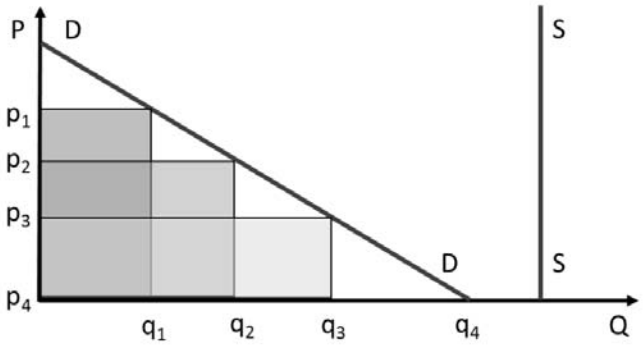

Figure 3 Quantity based price discrimination (second degree)

consumed. Clearly, a win win situation. An introduction of vignettes may not exclude other pricing mechanisms such as toll booths and electronic pricing systems. On the contrary, just like in telecommunications, there may exist a multitude of packages finely tuned to price discriminate and extract the maximum of revenue.

Cost structures based on large fixed and "sunk" costs induce pricing conduct based on price discrimination of second degree [8]. The marginal cost curve is so low that is practically inexistent, and with the average cost curve constantly falling to the point of capacity congestion SS, makes the highway a natural monopoly.

3.2 The lighthouse in economics

Many economists used the lighthouse as an example of a pure public non excludable and non-rival good. In 1974, Ronald Coase challenged the view that lighthouses are public goods since private provision did occur in the past. But how were they financed if exclusion wasn't possible? Mostly by bundling their service with the services of the nearby harbour. Enter revenue management and the most diverse pricing mechanisms.

On the issue of lighthouses Stiglitz wrote: "The costs of a lighthouse do not depend at all on the number of ships that sail past it." [23] This is also the case of a highway operation. The costs of a highway does not depend on the number of cars driving on it.

Now, imagine a radio station or a mobile telephone operator. The costs of radio station and telecommunication operation are also fixed and sunk and mostly independent of the number of users (less in the former, and more in the latter case), but dependent on the covered area. There is no queue in the ether. The opportunity costs of usage and the marginal costs of usage are both nil or close to zero. Nevertheless, the costs of the lighthouse, of the radio , of the telecommunication infrastructure or of a highway need to be recovered.

3.3 Revenue management

A necessary condition for Pareto efficiency is that the marginal willingness to pay must equal marginal cost [26]. The condition has several implications. Firstly, it must hold if the allocation is to be economically efficient. Secondly, the condition does not say anything about any particular unit of consumption except the last one that its price must equal its opportunity cost of usage which is zero. Thirdly, to be efficient if such pricing fails to recover total costs, the pricing scheme must be able to recover costs and needs to be independent of the incentive to use the road. One of such schemes is the vignette system.

Obviously, since the system of pricing is detached from the quantity consumed, it effectively constitutes a price discrimination in terms of the average price paid by the user per travelled distance. It is a price discrimination of second degree as it effectively gives unlimited privilege of use within the time span of a vignette. Unlimited privilege does change consumer preferences and incentives. According to Vrtic et al., the annual vignette in Switzerland, for example, turned out to be unsatisfactory with regard to demand management [27]. Concerning social acceptability aspects the social dilemma of self-interest against social-interest is fundamental and in Switzerland the personal self-interest is three times stronger than the social interest concerning road financing mechanism designs. Most importantly, social support for alternative mechanism designs is mainly influenced by public problem perception and perceived effectiveness of a mechanism design. [27]

In most European countries, fuel taxes make up about half the retail price of fuel. In addition, each car driver who wants to use the highway system in 14 European countries needs to buy a one-year vignette. The revenues raised by the fuel tax and the vignettes are spent on the expansion and maintenance of the road infrastructure. However, a certain amount of revenues goes into the general federal budget. Under the principle of a unitary budget, no expenditures are directly connected to any revenues, but all revenues contribute to all expenditures. This means, the vignette is a form of tax and not a charge for a service. [25, 27]

4 Organisational aspects of highway operation

Four distinct operations or functions regarding infrastructure management and organisation need to be performed: provision with construction, operation with maintenance, finance, and consumption allocation. These four roles need not be performed by a single provider or management organisation. The finance role does not need to be the same as the allocation mechanism. The question of what roles shall be performed by what organisational unit is open to debate, and even the field of economic organisation has no definitive answers. For example, there is nothing in the positive economic science that implies that highways need to be priced. Or that highways should not be financed directly from income taxes.

Let us suppose that the construction function has been awarded to the best (lowest cost) bidder and financed by the most affordable line of credit that can be

given to a sovereign debtor. The role of everyday management and organisation may be outsourced to an external service provider or performed by a governmental management organisation. Even if vignettes are chosen as the most appropriate method of finance, the question of maintenance organisation remains open. There are two broad possibilities branching into several other smaller variants.

Firstly, there is the possibility that the present concession contract holders remain in service and receive either a fixed or a variable compensation. The agreement is then valued as a swap between present cash flows and either fixed or variable cash flow alternatives that are going to be proposed to the concessionaire.

Secondly, there is a possibility of either a voluntary buy-out of concessionaires or their outright expropriation with subsequent costs of litigation, compensation, as well as other pecuniary costs such as loss of country reputation or worse.

Thirdly, the organisation of the maintenance may be conceded either as a whole (the entire network) for a certain duration, or parcelled into space-, duration-, and quality-dependent subsections on separate auctions. There are three basic models that come to light: the British, the German and a fully private model. In the UK, the public highway segments are under maintenance agreements by different corporations. The remuneration is conditional on maintenance activities and traffic frequency. But, these agreements were agreed upon under the circumstances of the veil of ignorance where traffic frequency was unknown to the government and the competing concessionaires at the auction. In Germany, the entire public highway network is under public ownership, and only the maintenance jobs are auctioned and given to the best bidder for every single case separately. Basically, the choice is between a centralised operational hierarchy, giving under concession (outsourcing) only the segments of the overall operation that cannot be performed by the governmental entity, and a network of smaller and independent concessionaires bidding for road segments that can be independently operated, with total operational freedom afterwards. It is a choice between hierarchies and networks at every operational level of organisation [15].

The German case offers less redundancy and idleness of maintenance facilities and personnel, whereas the British system offers more readiness and security. If maintenance cots are negligible, a lot of security may be had for low additional cost under British-type mechanism-design. If the road network to be maintained is as vast and dense as in Germany, efficiency gains may be achieved by additional competition under German-type mechanism design. The elastic supply and demand curves for road maintenance given in Germany by a vast road network and large number of contractors makes the German-type mechanism design optimal for Germany. The Germans treat the question of road financing (revenue collection) separately from the question of investment. Revenue collection mechanism design is based on relative collection efficiencies, Ramsey taxes, and fiscal policy principles. The road construction is based entirely on social cost-benefit arguments. The road is to be constructed where and when the present value of the accruing social benefits is greater than the corresponding social costs.

The question of road pricing is an economic one and is only partially conditional on the level of privatization. If the opportunity cost of usage is nil, it is economically (allocatively) efficient to set the price of usage to zero. Even for a private operator. The private operator would then need to discover for himself the optimal pricing mechanism design [1, 14]. The question of financing is then a separate question to be resolved according to the efficiency of various public financing policies at disposal. There is nothing in this regard to stop the government from disregarding the user pays principle. The user pays principle is not an economic principle based on efficiency, but an ethical one. The "user pays" principle is primarily based on the notion that the underlying good or service is not a pure public good as commonly accepted in economics [12, 16, 17, 18, 19, 22].

5 Conclusion

The question of highway pricing has been blurred by irrelevant arguments in the past. It is an economic issue. If the opportunity cost of usage is nil, it is efficient to set the quantity dependent price of usage to zero. The question of finance is then a separate question of revenue management to be resolved according to the efficiency of various finance policies at disposal. Fixed charges, variable charges, and flat rate pricing systems are available. In case of congestions, dynamic pricing with peak load pricing stay at the disposal. The choice of one pricing method does not necessarily exclude the others. The author prefers the vignette as it gives the widest possible set of non quantity dependent revenue management possibilities. Nevertheless, the transition to a system of vignettes poses a political welfare transfer challenge. By saying, there are no losers from the abolishment of the per use payment systems, it is not meant there is no one who shouldn't adjust his economic behaviour. Distance-dependent tolls are still the preferred pricing systems, in contrast to area licensing and time-dependent tolls. Nevertheless, the tide is turning and more and more countries are introducing vignettes. Unfortunately for Croatia, the economic discussion about optimal allocation mechanism design for highways turned political, and the elites lack the economic knowledge to provide such a design.

The purpose of this paper was to try to un-vignette the problem of vignettes: to try to un-blur the discussion from irrelevant arguments and bring the discussion back to the economics table. The author hopes it is just a start of a truly scientific discussion.

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