New technology adoption and the rule of law

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Abstract
The environmental technologies almost always comply with regulation that, in turn, is interdependent to the quality of institutional environment. In order to assess the effects of regulation on the adoption of environmental friendly technologies, it is important to understand the interaction between regulation and rule of law. Our model demonstrates the importance of reinforcing the rule of law for environmental friendly technology adoption. We show that when the rule of law is strong, the pollution abatement standard is more efficient and leads to more frequent adoption of environmental friendly technology. Reinforcing the rule of law leads to a better second best resources allocation, discourages rent-seeking and increases welfare.

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1. Introduction

Policy and institutional quality are supposed to be interdependent. A strong institutional environment is the result of successfully implemented policies, while well functioning policies are grounded on high quality institutions. Understanding this relationship is crucial for economic development and is particularly important for societies that have undertaken drastic changes, such as transition economies. In such a context, institutions and policies are involved in the process of continuous changes, influencing and reinforcing each other. Dysfunctional policies in these societies are often the result of a weak institutional environment. Reinforcing the institutions may be an example of reform that leads to improve economic policy (Infante and Smirnova 2009).

In this paper we discuss the influence of favorable economic institutions on the regulator's policy. Particularly, we analyze the "rule of law" institution as one of the important institutions influencing economic policy. Curiously, the definition of the rule of law is often given as a partial definition of the institutions. In particular, the rule of law is characterized "by the existence of universally known, accepted and enforced rules that govern all societies interactions" (Cervellati et. al. 2008), while "institutions are the rules, enforcement characteristics of rules, and norms of behavior that structure repeated human interaction" (North, 1989). Intuitively, the main difference between the two concepts is the distinction between the formal and informal rules that govern the society. Institutions may refer together to formal and informal rules, while the rule of law is based exclusively on formal rules or explicitly on laws.

2. Rule of law measure

The similarity in definitions underlines the importance of rule of law among other institutions that was captured by some authors. Most commonly the rule of law is measured as property rights protection. According to Donnelly (2006) who underlines that the rule of law "has a long-standing association with the protection of civil liberties … since under the rule of law the citizens are protected by law against the violence", the approximation of property rights protection to the rule of law is straightforward. Using this approach Acemoglu and Johnson (1993) show the importance of this aspect in a micro-founded analysis. Similarly, Gradstein (2004) represents a growth framework model that reflects the importance of property rights protection. Grossman (2001) concentrates attention on the creation of property rights, describing a general equilibrium where agents allocate time and effort to create the property rights. Acemoglu and Verdier (1998) consider the influence of corruption on enforcement of property rights. Shleifer and

Vishny (1994) demonstrate the importance of property rights distribution as a key element in solving the excess labor problem.

There have been some contributions that consider the rule of law under other aspects. Cervellati et. al. (2008) interpret the rule of law as the presence of a social contract that limits the conflicts of society. As opposed to the rule of law, the authors consider the state of nature, i.e. a situation where a society is involved in a conflict. Hoff and Stiglitz (2008) measure the rule of law as the demand of political forces to introduce the rule of law as reform that would benefit the politicians. Easterly (2006) sees the rule of law as the mechanism by which the social cohesion affects growth. Donnelly (2006) gives another plausible and simple measure of the rule of law – the legitimacy by which the state provides security for its citizens. Finally, the importance of legal origins, as the fundamentals of the rule of law, is emphasized in Beck, Demirgüç-Kunt and Levine (2003) and in Acemoglu et. al. (2001).

There can be noted a common feature of these approaches which is the tendency to decrease disorder by reinforcing the rule of law. The theory of the existing tradeoff between disorder and dictatorship was described by Djankov et. al. (2003). The authors argue that any society can be allocated along the institutional possibility frontier which is a kind of utility curve drawn between excessive order and excessive disorder, which are both evils for a society. The position of the society on the institutional possibility frontier is defined by its institutional environment. Reinforcing institutions permits to shift along the curve and to shift the curve itself, where the movement versus the origins of axes is welfare improving. Clearly, developed democratic societies with a strong rule of law obtain a better position on the institutional possibility frontier with respect to developing and transition societies that may be easily trapped in excessive order or disorder due to the weakness of institutions. Reinforcing the rule of law may represent an example of the reform that could contribute to more successful allocation of such countries.

3. Rule of law and adoption of environmental technologies

Discussing and understanding the role of rule of law in the economic policy is central. In cases where the market has to comply with state regulations, favorable economic institutions in the form of rule of law, are the background for functional policies. One of the vivid examples where the rule of law plays a crucial role is the adoption of environmental technologies. In fact, the environmental issues represent a good background for studying the interdependency between institutions and policy. The first reason is the actuality of environmental problems: the introduction of environmental friendly production technologies are nowadays at the center of attention in many countries. The second reason is that the environmental controls almost always comply with regulation. The pollution control technologies are rarely adopted without regulation stimulus (Lovely and Popp 2008), hence are the result of the quality of institutions, and particularly, of the strength of the rule of law.

The studies of environmental technologies may be divided in three general categories: the first category includes the works dedicated to the diffusion of new environmental technologies (Kerr and Newell 2003, Lanjouw and Mody 1996, Wiess 1994); the second offers the analysis of the regulation standards (Gray and Shadbegian 1998, Snyder et. al. 2003, Lovely and Popp 2008, Mookherjee and Png 1995); the third is concentrated on the emissions intensity analysis (Stern et. al. 1996, Arrow 1995).

Few recent works try to explore the links between the quality of institutions and the adoption of environmental friendly technologies. The majority of these studies are concentrated on a certain production sector or industry. The model of Lovely and Popp (2008) demonstrates a positive relationship between successful regulation of coal-fired power plants and, among other parameters, international economic integration. As Lovely and Popp (2008), we concentrate our attention on regulatory stimulus to adopt technology in non-highly developed economies and analyze the political economy decision on emissions abatement standard. However, while they focus on how adoption of environmental regulation is influenced by the availability of new technology, we analyze how it is influenced by the quality of the rule of law institution. Mookherjee and Png (1995) analyzed theoretically the links between an optimal compensation policy for corrupt official and the level of pollution. Our model considers a rent-seeking mechanism that is similar to that of Mookherjee and Png (1995), where the entrepreneurs and inspectors are involved in corruption activities by falsification of reporting and delaying payments. We also find that corruption has a negative effect on adjustment of pollution abatement standards. Finally, another model that links environmental technology with institutional environment is that of Kerr and Newell (2003) who show that the economic instruments for environmental protection lead to the adoption of new technologies with more flexible policies being more efficient in the petroleum industry. We confirm the authors' results on the functionality of instruments such as pollution taxes and on the significance of the

technology costs for the new technology adoption and that stricter abatement standards raise social welfare.

While our findings confirm the results on the links between technology adoption and regulator policy found by the above authors, our paper focuses primarily on the effects of the reinforcement of quality of the rule of law for the adoption of environmental friendly technologies. To our knowledge, there is no study that explores this aspect. We make an attempt to fill this gap and provide a theoretical framework of this relationship.

4. Model

4.1. Regulator

In a closed economy, the entrepreneurs produce output (*y)* by utilizing a production process based on environment unfriendly technology that generates a disutility (α) for all economic agents (the total number of agents is one). The regulator that maximizes the social welfare *(W*) takes the decision to regulate the pollution and induce the entrepreneurs (*n*) to install environmental friendly technology at the cost *c*. To do this, the regulator employs some inspectors, among the entrepreneurs, to enforce the regulation. The inspectors incentivize the technology choice through subsidies (*s*) to entrepreneurs (*m*) who adopt the environmental friendly technology, and fines (*f*) of entrepreneurs who continue to utilize the polluting technology. The salary of the inspector is given by *w*. We suppose that an inspector may be self-interested and can practice corruption.

The regulator chooses the complete abatement of emissions, neutralizing the disutility α, so that all of the entrepreneurs adopt the pollution-control technology. The decision to regulate is taken when the welfare level in the case of intervention is greater than that without intervention. That is, $W_1 \leq W_2$, where:

$W_1 = y - \alpha$ *(1)*

$W_2 = yn - cn$ *(2)*

and $½ \leq n \leq 1$, assuming that one inspector monitors one entrepreneur.

The regulator's policy consists of the following instruments: the inspectors salary (*w)*, the subsidies for the entrepreneurs who adopt environmental friendly technology (*s)*, and the fines that the entrepreneurs pay when they utilize the environment unfriendly technology (*f)*.

4.2. Entrepreneurs and inspectors

Since the adoption of environmental friendly technology is costly, the entrepreneurs adopt it only with regulatory stimuli. These stimuli are expressed as fines and subsidies. We suppose that the subsidy takes the form of tax alleviation, hence, the entrepreneurs who adopt the new technology pay less taxes to the regulator.[1]

Both, subsidies and fines are activated only when the inspector undertakes the monitoring, so that, subsidies and fines are obtained/paid with a probability $\frac{1-n}{n}$. Subsidies and fines represent a good terrain for inspectors' illegal rent-seeking activities. We presume that an inspector may be self-interested and can practice corruption.

The entrepreneurs who adopt the environmental friendly technology may be involved in extortion and asked to pay a bribe (*b*), in order to obtain the subsidy. The entrepreneurs who continue to utilize the environment unfriendly technology can be also asked to pay a bribe so that the inspector reports that they utilize new technology. Obviously, in this case $b \leq f$.

Inspectors receive a salary, *w*, paid by the regulator. With the probability of practicing corruption, *r*, the inspectors apart from salary, may obtain the bribe *b*, from both types of the entrepreneurs. In the event of the corruption being reported by the entrepreneurs, with probability *d*, the dishonest inspector gets fired, losing salary and other gains.

4.3. Measure of the rule of law

According to Donnelly (2008) who describes the rule of law as the guaranty of the government to protect its citizens against violence, and Rijckeghem et. al. (2000) who use as a proxy of the probability of

[1] For the sake of simplicity, general taxation is omitted in the model.

corruption detection the index of the rule of law, we measure the rule of law by the probability that an extorted or corrupted entrepreneur appeals to a court. Hence, in the case an inspector requires bribes there is a certain probability that the inspector is reported. We assume that the bribe is not greater than the amount of fines for the use of the environment unfriendly technology and suppose that the regulator may penalize the inspector.

Following Donnelly (2008), who states that "when citizens can bring disputes concerning rights to court rather than fight in the streets, the rule of law is enhanced", we consider the rule of law is reinforced when the probability of being reported increases from zero to one. On the contrary, the rule of law is less strong if the probability of being reported decreases.

4.4. Pollution abatement policy

4.4.1. The sequence of events

At the first stage, the regulator defines the allocation of entrepreneurs and inspectors considering the following factors: a) the cost of new technology adoption, b) the output of entrepreneurs, c) the probability of practicing corruption and extortion and the level of bribing, d) the strength of rule of law. At the following stage, the abatement standard is calculated by comparing welfare functions, that depend on the allocation of entrepreneurs and inspectors, in the case of intervention and that without it. The decision to intervene into the production sector is taken when the actual level of pollution is greater than its abatement standard level. Once the decision is taken, the regulator defines the levels of subsidy, fine and inspector salary that allow to bring allocation of entrepreneurs to that of second best, where all the entrepreneurs produce with environmental friendly technology and external harm is neutralized.

The state of the rule of law is captured at the first stage, since in defining the number of inspectors the regulator considers the probability that entrepreneurs may report the inspectors involved in rent-seeking activities. In this way, the second best allocation of agents and the abatement standard depend on the strength of the rule of law.

4.4.2. Second best allocation

In order to define the allocation of entrepreneurs and inspectors, the regulator establishes that the gains of entrepreneurs who adopt the new technology are greater than for those who do not adopt it, considering that fines, paid by entrepreneurs who continue to utilize the environmental unfriendly technology, should not exceed the output produced by these entrepreneurs[2], so that $y \geq f$. To minimize the rent-seeking activities, the regulator sets that the gain of the honest inspector is greater than that of the corrupted inspector. Finally, the regulator faces budgetary limitation. The budget incomes consist of the amount of fines collected by the honest inspectors, given the probability of monitoring. The budget expenditures consist of: a) the amount of wages paid to inspectors, considering an amount of wages that returns in the case the inspector is corrupt and reported by the entrepreneur, b) the amount of subsidies released for the adoption of environmental friendly technology, given the monitoring probability. Obviously, the entries of the regulator are greater then the expenditures. The last requirement is the complete neutralization of external harm, so that all the entrepreneurs adopt a new technology and $n=m$. The regulator budget and the individual payoffs of both types of entrepreneurs and inspectors are drawn in Figure 1.

4.4.3. Abatement standard

The second best allocation of entrepreneurs (where $n=m$) and inspectors ($1-m$), resulting from satisfying all of the above requirements is given by:

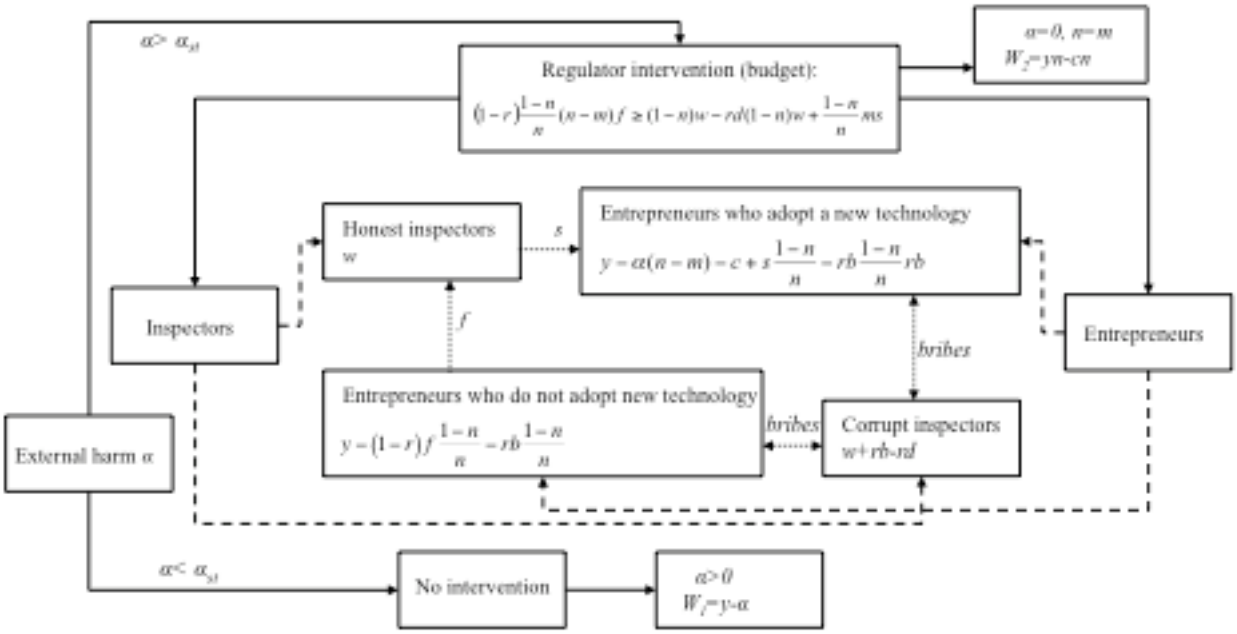
$$m = \frac{dy - dyr + brd - b}{dc + dy - dyr - b + brd} \tag{3}$$

Now we are back to welfare functions (1) and (2) and by comparing the welfare in case of intervention and in the case without intervention, and calculate the abatement standard, given by:

[2] We suppose $y=f$.

$$\alpha_{st} = c\frac{2dy - dyr + brd - b}{dc + dy - dyr - b + brd} \quad (4)$$

Figure.1 Pollution abatement strategy: payoffs, constraints, flows and outcomes



Source: Authors' illustration

Therefore, the regulator applies the pollution abatement policy in the case:

$$\alpha \geq \alpha_{st} \quad (5)$$

The greater is α_{st} the lesser is welfare, since a relatively high level of pollution would be required to be neutralised through the regulator policy. If Eq.(5) does not hold, the regulator will not enact an abatement policy, since the benefits of abatement are not large enough to offset the costs.

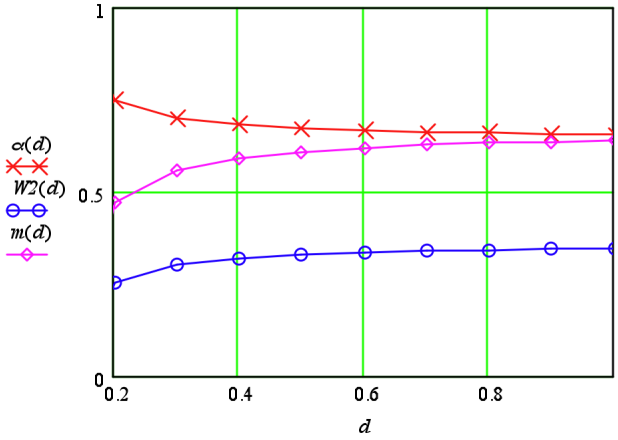
4.5. The quality of the rule of law

Figure 2 illustrates the importance of the rule of law reinforcement for the regulator policy of pollution abatement[3]. The impact of the rule of law becomes evident by calculating the derivatives respect to *d* of Eq. (3) and Eq. (4). Given that $\frac{\partial m}{\partial d} \geq 0$, improving the quality of institutions that enhance the entrepreneurs to report the violation of their rights leads to the increase of the number of entrepreneurs adopting the environmental friendly technology. In the presence of high quality of the rule of law, the regulator may introduce less inspectors, avoiding loosing production output. As a consequence, the increase of the number of adopters has a positive impact on the welfare (W_2) as Eq. (2) demonstrates. From Eq. (3), we can note another mechanism, that of new technology diffusion. As the number of new technology adopters increases, the cost of the technology (*c*) goes down, keeping other parameters constant, incentivising further the environmental friendly technology diffusion.

[3] Coefficients taken for Figure 2 and Figure 3, normalised to a unit, are the following: *y=1, c=0.5, r=0.1, b=0.1, w=0.8, m=0.55.*

On the other hand, the relation between the strength of the rule of law and the abatement standard is inverse: $\frac{\partial \alpha_{st}}{\partial d} \leq 0$. The higher is the quality of the institution the lower is the abatement standard, that means more effective external harm neutralisation. The mechanism behind the above relationships is given by the regulator instruments of pollution abatement.

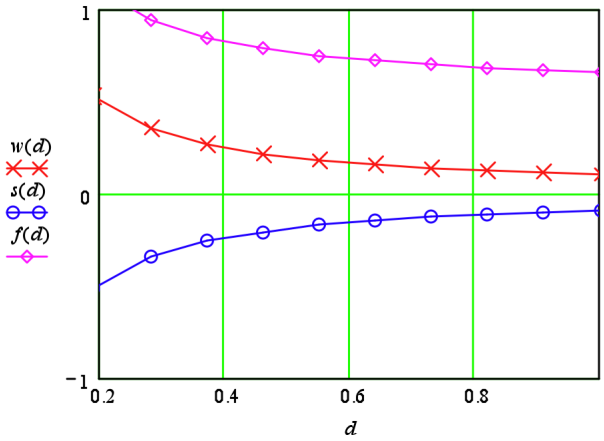
Figure 2. Reinforcement of the rule of law: the impact on entrepreneurs' allocation (*m*), welfare (W_2) and abatement standard (α_{st})



Source: Authors' illustration

Finally, the regulator defines the instruments of pollution abatement policy: subsidies (*s*), fines (*f*) and inspector's salary (*w*). The influence of the rule of law reinforcement on these three instruments is illustrated in Figure 3. Both fines and subsidies (recall that subsidies are considered as a form of tax alleviation) decrease with the improvement of the quality of the rule of law. Clearly, in the presence of weak institutions where the state cannot guarantee the respects for rights, there are more incentives needed to induce the entrepreneurs to switch to environmental friendly technology. The "carrot" in the form of subsidies and the "stick" in the form of fines should be greater with respect to a situation where the rule of law is advancing and the agents are encouraged to take their cases to court and abide by the result.

Figure 3. Reinforcement of the rule of law and the impact on the instruments of regulator policy: subsidies (*s*), fines (*f*) and inspector's salary (*w*).



Source: Authors' illustration

The inspector's wage decreases in the probability of being reported for bribing or extortion. The more easily the entrepreneurs report, less wage is needed for an inspector. In fact, at a low quality of the rule of

law more incentives are needed for an inspector to avoid engaging in rent-seeking activities, so the wage should be relatively high to prevent corruption. Equation (6) confirms this relationship:

$$r = \frac{wc - \alpha w + \alpha c + \alpha y - 2cy}{(c - \alpha)(b - y)} \tag{6}$$

where $\frac{\partial r}{\partial w} \leq 0$. Therefore, the probability of being involved in corruption increases with the decrease of the inspector's wage. From the above equation it is also possible to deduce the harmful effect of illegal rent-seeking on the pollution, which increases with the growth of corruption.

5. Results

While recent literature often considers separately the issues of the adoption of environmental technologies and the reinforcement of the rule of law, these two issues are strongly interdependent. We have built a theoretical framework to demonstrate the importance of reinforcing the rule of law for more efficient environmental technology adoption. Being one of the important institutions for government regulation, the rule of law is measured as a probability of appealing to the court by corrupted or extorted entrepreneurs.

The model demonstrates that reinforcing the rule of law leads to the increase of the number of the entrepreneurs who adopt environmental friendly technology, so decreasing the costs of this technology and increasing social welfare. We show that under a strong rule of law the pollution abatement standard is more efficient and permits to neutralise pollution at lower emission levels. Moreover, with a stronger rule of law, pollution may be neutralised with lower costs of regulator intervention and with less resources drainage from rent-seeking activities. As a result, reinforcing the rule of law may represent an example of a reform that may contribute to more successful environmental regulation.

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