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by

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Geographic Allocation of OSS Contributions: The Role of Institutions and Culture[§]

Sebastian v. Engelhardt^{}, Andreas Freytag^{**}*

Abstract

So-called open source software (OSS) is marked by free access to the software and its source code. Copyright-based OSS licenses permit users to use, change, improve and redistribute the software, which is designed and developed in a public, collaborative manner. High quality OSS products like Linux, Apache etc. are developed by thousands of volunteers, who often do not receive direct monetary reward. Thus, OSS seems to be an example of a ‘private provision of a public good’, and some argue that OSS is a ‘new intellectual property paradigm’ for the digital economy. Therefore, OSS has been in the focus of economic research for some years.

However, it is still not known which institutional and cultural factors favor OSS development, although the differences of countries in OSS activities can not be solely explained by GDP, education and internet access. For this reason, we perform a cross-country study analyzing how the number of OSS developers per inhabitants and the level of OSS activity of a country depends on institutional and cultural factors. We make use of data about OSS developers registered at SourceForge, and are able to assign 94% of them to their countries. We then run regressions with several institutional and cultural factors.

Our findings are that a culture characterized by individualism/self-determination is in favor of OSS. Also, social capital in terms of interpersonal trust has a positive impact on the number of OSS developers as well as on the OSS activity level. The openness to novelty is relevant only with respect to scientific progress, i.e. an optimistic view of scientific progress is significantly positive. While the attitude towards competition was never significant, less regulated countries have more OSS activists and activity. Furthermore, the protection of intellectual property rights has (if all) a positive impact.

Our study contributes to the understanding of the impact of cultural and institutional factors in general as well as in particular with respect to OSS. Additionally it also improves the understanding of OSS. OSS has similarities to technical science and scientific culture, is a public good game with the contributions are a means to an end. OSS is a new intellectual property right paradigm and is based on an entrepreneurial spirit.

Key Words: Open Source, Culture, Institutions, Social Capital, Trust, Regulation, Entrepreneurial Spirit, Individualism, Intellectual Property Rights

JEL Code: B52, L17, L86, O34, Z13, Z19

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1 Introduction

The software industry is characterized by innovations not only at the level of products but also at the level of market organization, i.e. *institutions*. In the case of open source software (OSS), the source code—the human-readable recipe of a software program—is ‘open’ (disclosed). This implies general access to the software and its source code, as well as the right to read, modify, improve, redistribute and use it. This principle of openness is codified in the (copyright based) OSS licenses. Hence, OSS seems to represent a “new intellectual property paradigm” (Maurer & Scotchmer, 2006), i.e. a new type of ownership concept that leads to different allocations of intellectual property rights and different modes of organization as compared to so called proprietary software. OSS is developed by a decentralized but nevertheless well organized ‘community’ that consists of thousands of volunteers who develop software, often without direct monetary reward, and firms that are engaged in OSS. Some OSS – like the Apache Webserver software (see figure 1) – have a remarkable market share. Thus, OSS appears to be a successful example for a “private provision of a public good” (Johnson, 2002).

--- [Figure 1 about here] ---

OSS has been in the focus of economic research for some years. For instance, economic research has analyzed the effects of OSS on *competition* (Casadesus-Masanell & Ghemawat 2003, Bitzer 2004), as well as *open innovations* (von Hippel & von Krogh 2003, von Hippel 2005) and *firm investments in OSS* (e.g. Baake & Wichmann 2004, Henkel 2006, Lerner et al. 2006, Rossi & Bonaccorsi 2006). Another important branch of the literature is dealing with the motivations of OSS developers, asking the question of “Why should thousands of top-notch programmers contribute freely to the provision of a public good?” (Lerner & Tirole 2002), i.e. is analyzing the *incentives* and extrinsic and intrinsic *motives*. There is much literature dealing with this question on the individual level, both from economics and other social sciences.¹ We are interested in the conditions for OSS activities on the level of society; in other words we take into consideration the microeconomics of OSS and search for the conditions for these aspects. As we do a cross-country study, this implies that the number of OSS developers of a country is shaped by the country’s institutional and cultural factors. Hence potential dependent variables are the number of OSS developers per capita as well as the level of OSS activities. Making use of Williamson’s analytical framework (Williamson 2000, see also figure 1), it seems obvious that economic research so far has focused on the level of resource allocation and employment (level four, the main focus of neoclassical economics) and the level of gov-

¹ Schiff (2002) provides an overview of early economic contributions to this topic. A prominent explanation referring to extrinsic motivations is the acquisition of a reputation-signal (Lerner & Tirole 2000), but intrinsic motives also play a role. An empirical examination of the motives can be found e.g. in Ghosh et al. (2002). See also Rossi (2006) on this topic.

ernance (level three, „the play of the game“). Hence, with respect to OSS, there is still lack of knowledge regarding the levels one and two, i.e. regarding the so-called “embeddedness” (informal institutions, customs, traditions, norms, religion) and the institutional environment (formal rules of the game, esp. property). Our paper aims to fill this gap. For this purpose, we perform a cross-country study analyzing how the per capita number of a country's OSS developers registered at SourceForge² depends on institutional and cultural factors. In particular, we take into account aspects of the legal system and regulation, social capital, the openness to novelty, the degree of individualism/self-determination of a society as well as its attitude toward competition.

--- [Figure 2 about here] ---

The remainder of the paper is structured as follows: In section 2, we discuss the theoretical foundations of the paper and derive the hypotheses for the empirical study. In section 3, we operationalize the variables and describe the data and its sources. This data is used to perform the empirical assessment in section 4, where the regression results are presented. In section 5 we compare and discuss the results before we end with a summary in section 6.

2 Theoretical Considerations and Hypotheses

Countries differ in the number of OSS developers per capita as well as in the level of OSS activity. These differences can not be solely explained by differences in GDP, education and aspects of ICT, like access to the internet. Thus, it is reasonable to examine further country-specific factors that influence OSS. Therefore we analyze the impact of institutional and cultural factors on OSS. In other words: We assume that the decision to become an (active) OSS developer is shaped by institutional and cultural factors that belong to level one and two of Williamson's framework.

In general, cultural and institutional factors shape human interaction (see also 2.1) and therefore have an impact on the microeconomic level. Hence, in order to derive hypotheses about the influence of institutional and cultural factors on OSS developers and their activities, we will link insights about the microeconomics of OSS with the level of institutional and cultural factors.

This is a relatively new approach. The only study (we are aware of) linking cultural factors with the geographics of OSS developers is Ramanujam (2007). It is an interesting paper, although one might criticize that the theoretical foundation of the study could have been more

² SourceForge is an internet platform for OSS developers to control and manage OSS development. In a sense it is a virtual center where the developers of a certain OSS project can meet, discuss, coordinate their tasks, upload new developed codes etc. SourceForge is seen as the world's largest site hosting OSS-projects. While access to the developer-areas needs registration, finished version of software can be downloaded by anybody.

elaborated and deepened.³ Ramanujam takes data from Ghosh (2006) and uses Hofstede's cultural indicators in order to analyze how differences in national culture affect or influence the participation in OSS. He links the geographical distribution of developers with the four dimensions of national cultures considered by Hofstede. Ramanujam states a positive correlation between the share of OSS developers and 'Individualism', whereas 'Power Distance' and 'Uncertainty Avoidance' are negatively correlated each. However, the results should be interpreted with care, as there is no correction or control for aspects like number of inhabitants, GDP, internet access etc. Furthermore, with respect to OSS contribution Ramanujam (2007) distinguishes only four regions, whereas the paper at hand runs regressions with data from about 70 countries, and analyzes several cultural and institutional factors including norms and attitudes.

2.1 The role of culture, informal and formal institutions

Nowadays it is consensus among economists, that institutions “matter”, as they define the incentive structure of a society and are therefore the underlying determinants of economic performance (North 1994, p 359). This means that human interaction is structured and shaped by “humanly devised constraints”, and these institutions “are made up of formal constraints (e.g., rules, laws, constitutions), informal constraints (e.g., norms of behavior, conventions, self-imposed codes of conduct), and their enforcement characteristics.” (North 1994, p 360)

Hence, we distinguish between formal and informal institutions, being aware of the interaction and interdependencies between them (see e.g. Pejovich 1999). The *impact of formal institutions* on economic activities is widely discussed so we do not see the need to explain this here further in a general way. But how does culture affect economic activities?

A first answer is given by North himself, as he points out that the informal institutions belong to „the heritage called culture“ (North 1990 p 37). This is in line with Williamson's framework, as his level 1 (“embeddedness”) is characterized by the set of informal institutions, namely customs, traditions, norms and religion (Williamson 2000, see also figure 2). Therefore some economists analyze culture in terms of informal institutions like social conventions or individual beliefs like interpersonal trust or (rational) cultural beliefs that are self-enforcing (Guiso et al. 2008, Myerson 2002, Greif 1994, p 915).

However, although informal institutions belong to the sphere of culture, not everything belonging to culture is an (informal) institution. In other words: although culture shapes human

³ Ramanujam hypothesis is that “Cultural differences amongst the programmers from different regions lead to measurable differences in their participation in the open source movement. In other words national cultural differences influence the participation of programmers in development of OSS” (Ramanujam 2007, p 16). When interpreting his results he gives some plausible explanations for his findings. Nevertheless, the in some sense inductive study seems a bit vague with respect to theoretical explanation and/or foundation, especially as there are no controls for other possible impacts like education, internet access or population and so on.

interaction, some parts of culture are not institutions by definition, as they lack of enforcement characteristics. Nevertheless, this part of culture also affects economic behavior, as it is linked to individual values and preferences. Research focusing on this aspect of culture are e.g. Rabin (1993) and Akerlof & Kranton (2000, using the concept of ‘identity’). Bowles (1998) treats preferences as cultural traits, and Bisin & Verdier (2001) model intergenerational cultural transmission as transmission of preferences, while Fernandez & Fogli (2009) analyze the impact of culture in terms of preferences and beliefs on women’s work and fertility.

In addition, the different aspects and dimensions of culture can influence each other, and there are also interdependencies between the sphere of culture and formal institutions. How culture influences the implementation of formal rules was for example analyzed by Greif’s seminal article about the impact of cultural beliefs on the introduction of different organizations (Greif 1994). Other examples for research dealing with the interaction of culture and (formal) institutions are Tabellini (2008a, 2007), the research dealing with informal vs. formal institutions and the transition of economics.

We are not going to further discuss the literature on this issues⁴. For the purpose of this paper it is sufficient to know two things regarding the role of *culture*:

- First, culture has an impact on economics, as it influences economic behavior either in forms of *social conventions*, in forms of *beliefs*, or in forms of *individual values and preferences*.
- Second, culture “*embeds*” and thus shapes lower-level institutions. This means that certain cultural characteristics can foster or hinder the *implementation* and/or *functioning* of institutions.

2.2 The Phenomena of OSS and institutional and cultural factors

Being a social-economic phenomena, OSS development has several dimensions. These dimensions are interconnected and can overlap. We will now briefly give an overview of the aspects

⁴ Additionally to the literature already mentioned in the text there is a variety of research. The following list of further examples is not intended to be exhaustive, but rather to give an impression of the range of research on culture and economics. An overview and an introduction to the topic can be found in Fernández 2008, see also Guiso et al. 2006 for a summary of research. A discussion about the concept of culture in economic research is Heydemann (2008) vs. Nugent (2008), while Jackson (1993) discusses “culture, society and economic theory”. Scholars like Svetozar Pejovich and Eckehard F. Rosenbaum have analyzed the role of culture in the process of transition of (former) socialist economies (Pejovich 2003, Rosenbaum 2001). This is related to the interplay of on formal and informal institutions like e.g. Williamson (2009) deals with. Tabellini (2008b) analyzes norms and values on cooperation, taking into account (a) that individuals also value the act of cooperating per se. and (b) the social embeddedness of the players (“within a circle of socially connected individuals”). Henrich (2000) examines the impact of culture on ultimatum game bargaining, and Altvorsen (1986) examines games that “play people”. In “Belief in a Just World and Redistributive Politics” Bénabou & Tirole (2006) connect beliefs and voting in a model with an “American” and an “European” equilibrium in endogenously shared ideology.

relevant for the purpose of this paper. We will go more into detail in the following section when we derive our hypothesis.

OSS has similarities to *technical science* and *scientific culture*: Its principle of openness and reputation mechanism have similarities to what is called open science. Many OSS developers are at universities, and historically the idea of OSS comes from software-science and is somehow rooted in scientific culture. There is also the culture of helping each other and discussing problems in online-forums. Additionally OSS is – as it is about software development – connected to the search for new solutions. Finally OSS has a strong technical aspect: software can be seen as a logical machine, (see also the term “software engineer”) and is clearly connected to computers and the internet.

OSS is also a kind of a *public good game*, or collective action, that is *linked* to complementary assets on the individual level; in that sense, contribution to OSS is always *a means to an end*. Either because somebody (further) develops the code for own purpose, or because of receiving utility from doing so. In the latter case OSS is just an example of a (globally coordinated) hobby activity, a task that is done for self-fulfillment and self-determination. Other reasons are more extrinsically motivated, like building reputation signals or make money with so-called OSS business models, i.e. selling complementary products like service or hardware.

OSS is a new *intellectual property right paradigm*. The existence and success of OSS seem to challenge the conventional wisdom about the proper role of intellectual property rights. Although this is true to some extent, it is important to notice that the several OSS licenses (and the OSS business models) rely on copyright law, and that the governance of the different OSS projects are to some extent based on trademarks etc.

Another dimension of OSS is its *entrepreneurial spirit*: Beside the fact that there exist a lot of OSS business models, OSS projects are set up or supported by individuals who see the need for a certain solution. Thus OSS in general is based on the idea of individual initiative. One can subsume this spirit as follows: ‘If you see a bug, fix it. If you see the need for another feature, develop it. If you can't do so, then at least report/propose this.’ Clearly the openness of the code is a precondition here but a sense for pragmatic solutions helps also.

In the following section we will go more into details, hence discuss the different aspects of OSS. For each of these aspects we will develop a hypothesis of how institutional or cultural factors have an influence on OSS development. In some sense we break up the phenomena OSS into several elements, identify the more general, underlying aspects, and then connect these with the institutional or cultural factor that is (not) in favor of the particular aspect. It is important to notice that these general aspects are not exclusively linked to OSS. For example: We will argue that OSS is an example of an individualistic, self-deterministic behavior. In a

society with a strong culture of individualism/self-determination, we expect more individualistic, self-deterministic behavior. As OSS development is one of these behaviors, we expect to see more OSS. In other words: We do not intend to measure the characteristics of the OSS developers via country-level indicators. Thus, we do not claim that it is the high number of OSS developers that makes a country more individualistic/self-deterministic. We argue that it is the cultural spirit of a country that makes it more likely that individuals choose certain tasks with specific characteristics, in our case develop OSS.

2.3 The Hypotheses

This section derives the hypotheses. Before we discuss the interplay of the different institutional and cultural factors and OSS development in detail, we will first have to take into account a more technical aspect, i.e. the information and communications technologies:

As data about the geographic origin of OSS developers suggest (see section 3.1), most OSS contributions come from more developed countries. Therefore we have to control for GDP per capita and education. But beyond this we have to take into account the information and communications technology (ICT). There are three reasons why to do so. First, internet access is a technical precondition to participate in OSS, as without internet there is no access to the online community of OSS developers. Second, as OSS development is organized via the internet and is rooted in the so-called “hacker-culture”, it is in a sense part of the cyber-space culture. Therefore it is likely that without some internet experience, there are mental barriers to join the OSS community. Finally, some OSS activities are linked to OSS business models: although OSS is marked by free access to the source code, there exist several OSS business models. As the OSS code itself can not be a profit center, OSS business models are based on selling complementary products (Maurer & Scotchmer 2006, p 289, 290ff). This can be hardware like servers or mobile phones, premium versions or different kinds of service like maintenance etc. Having in mind this business character of OSS, it may be important to assess the potential size of a market, both for the supplier of OSS and the demander of OSS programmers. Taking this together our first hypothesis is:

H1: ICT is beneficial both for the number of OSS developers and the OSS activity level.

Let us come to the cultural and institutional factors. We will first focus on one aspect of OSS that reminds of *science*: OSS development is to some degree a collaborative way of developing *novelty*. The process of (open source) software development is to some extent a search for new solutions, i.e. an innovative process as such. Thus, OSS development is about “coordinating innovation” (Kugler, 2005). Additionally, the rise of OSS can be seen as an innovation at

the level of how to organize software development, and some authors discuss it as a new intellectual property paradigm (e.g. Maurer & Scotchmer, 2006) or put open source software in line with an „intellectual property revolution“ (Pisano 2006).

In this context we will make use of the notion of culture that connects *culture* with *preferences and values*: In societies that are more open to novelty, in particular that are more open to new ideas, a higher share of people would prefer new ideas. Such preferences are a good precondition for the adoption of the OSS model of software development and also for active participation, i.e. the search for new solutions. Therefore we expect the following:

H2: A preference for new ideas has a positive impact on the number of OSS developers as well as on the OSS activity level.

The second aspect is also related to science, i.e. the similarities to *technical science* and *scientific culture*: First, OSS has a strong technical aspect. OSS, being a novelty of the “cyber space”, is clearly connected to computers and the internet and therefore to the technical aspect of scientific progress. Additionally, software development is in some sense the art to build a logical machine, see also the term “software engineer”. Second, historically the idea of OSS comes from software-science and is therefore rooted in scientific culture. For example, the most known OSS license, the GPL, was developed by Richard Stallman. Richard Stallman worked in the MIT Artificial Intelligence Lab. As in the 1980s more and more software was closed (i.e. sold as “proprietary software”) Stallman started the GNU project in order to defend and foster a “free” – in terms of “open” – culture of software development. This finally led to the GPL licenses. Still today, the OSS community has “scientific-alike” aspects: There is a culture of discussing problems and helping each other in online-forums, and many OSS developers are at universities. Some Scholars have pointed out that the OSS principles, including openness and the reputation mechanism, have similarities to what is called open science (Dalle & David 2005, Lerner & Tirole 2002, Giuri et al. 2002).

We now argue that a positive attitude towards technical science and/or scientific progress at all is in favor of OSS. The reasoning for this refers again to *culture* in terms of *preferences and values*: Individuals with a preference for science/scientific progress will more likely be attracted by the scientific and technological aspects of OSS than those who do not have such preferences. Additionally, one might argue that such a pro-science *culture* (in terms of attitudes, i.e. preferences and values) support the science-alike *formal and informal institutions* of the OSS community. Based on this, we state the following hypothesis:

H3: A positive attitude towards scientific progress has a positive impact on the number of OSS developers and on the level of OSS activities.

We mentioned before, that one reason why contributing to OSS is *a means to an end*, is because the developers directly receive utility from doing so. For example, Hars & Ou (2002) found that “self-determination” was with about 80% agreement the strongest intrinsic motive. Other authors report that “fun” and enjoyment of programming work itself or of solving problems, and the joy of intellectual challenge are important motives for individuals to contribute to OSS (Luthiger Stoll 2007, Lakhani & Wolf 2005, Hertel et al 2003, Lakhani et al 2002). Thus OSS seems to meet values and preferences which are connected to a culture of individualism and self-determination.

So again, theoretically we refer here to the links between *culture* and *preferences and values*: In a culture with a higher degree of individualism/self-determination, one would expect that more people engage in individualistic hobbies, because of their preferences for self-fulfillment and self-determination. As research on the intrinsic motives of OSS developers suggest that OSS development is one activity that fits such preferences, we expect to see an impact on OSS development:

H4: The degree of individualism/self-determination of a society has a positive impact on the number of OSS developers as well as on the OSS activity level.

Although individual OSS contribution is a means to an end, i.e. is linked to (complementary) assets (i.e. intrinsic or extrinsic motives), the whole OSS development process still is a *public good game*, or collective action. This brings us to the aspect of so-called social capital: The term social capital is related to ties between people. While some refer to the number of ties only, others stress the features, strength or quality of such ties, which includes aspects like trust. Probably the most known (and widely accepted) definition of “social capital” is by Putnam (1993, 1995). Putnam states that social capital „refers to features of social organization such as networks, norms, and social trust that facilitate coordination and cooperation for mutual benefit“ (Putnam 1995, p 67). Therefore measures of social capital can take aspects like number of people somebody is (weakly) connected to, but also aspects like social, i.e. interpersonal trust and social engagement into account. We focus on interpersonal trust in this paper.

Thus, the theoretical concept (or aspect) of culture we refer to in this context is *culture* as *beliefs*, namely *interpersonal trust*. For the purpose of this paper it is not relevant where this country-specific level of interpersonal trust comes from (e.g. as result of a general “social” game, or from several sub-games of the country): What matters are the implications of (ex ante) interpersonal trust on the behavior of individuals with respect to the international public good game OSS. First, individuals with more trust will expect less free-rider behavior and more reciprocal behavior. Thus, they are more likely to enter the OSS contribution-game as

they will expect that it “can work”. Second, the literature on public good problems indicates that interpersonal trust has a positive impact on cooperation and reciprocate behavior (Yamagishi et al. 2005, De Cremer 1999, Ostrom, E 1998, Yamagishi & Yamagishi 1994). Hence having more individuals with higher interpersonal trust should yield more OSS contributions, more reciprocate behavior etc. from that specific country. Such behavior is then stabilized: the ex ante beliefs are supported by the outcome of the game as OSS is a *successful* public good game. To put it simple: People with high interpersonal trust fit better into the OSS community, as OSS depends on voluntary code-contribution and reciprocity is part of the OSS community culture (Gosh et al. 2002, Lakhani et al. 2002). Therefore we expect the following:

H5: Social Capital in terms of interpersonal trust has a positive impact on the number of OSS developers as well as on the OSS activity level.

So far, we have concentrated on intrinsic aspects (motives, preferences beliefs). Now we will turn to extrinsic motives, incentives etc. In particular we will focus on aspects of OSS that are linked to the enforcement, the enforcement mechanisms respectively, of particular institutions. We will first analyze an informal institution of OSS (the reputation mechanism) before we discuss the impact of the protection of intellectual property rights on OSS.

Beside the intrinsic motives already mentioned, reasons why contribution to the public good OSS is in some sense a means to an end are extrinsic motives and OSS business models. From the perspective of the individual, motives such as self-marketing, peer recognition and reputation within the community (Lakhani et al. 2002, Hars & Ou 2002) are mentioned. Furthermore, there are motives that are directly linked to career aspects, like the improvement of programming skills, i.e. the investment in human capital, and the aim to build up reputation signals for the job market (Lakhani & Wolf 2005, Hertel et al. 2003, Gosh et al. 2002, Hars & Ou 2002, Lakhani et al. 2002, in all cases these motive were stronger than the motives related to peer recognition). We will subsume these motives under the term “reputation mechanism”. Such an reputation mechanism of OSS is an incentive structure based on the idea to give reward for individual performance. Thus it is an example for the merit principle. In addition the relevance of such performance signals indicates some sense of competition, especially when it comes to the job-market. Thus we focus on an informal institution of the OSS community that has an explicit, i.e. peer enforced (positive) enforcement mechanism (you get the reputation from the other peers).

It is this *enforcement mechanism* itself that is of interest here if it comes to the role of *culture*: Positive attitudes towards the merit principle and competition foster and support such enforcement mechanisms of performance based reputation. First because if more people will

accept the idea of individual performance signals, more peers will be willing to give reward for good contributions and finally more people will see the need for and have a preference for the achievement of such signals. More theoretically spoken, we analyze here an example of how *culture* in terms of *preferences and values* can *foster or hinder* the functioning of *institutions*, namely the effectiveness of its enforcement mechanism. Thus in particular we argue that in a country with a more positive attitude towards competition and the merit principle, it is more likely to find software developers/students who engage in OSS with the goal to achieve reputation signals for “sportive” peer-competition or career aspects.

H6: A culture of positive attitudes toward competition and the merit principle has a positive impact on the number of OSS developers as well as on the OSS activity level.

We will now turn to the *de facto enforcement* of an *formal institution*: the *de facto* protection of intellectual property rights (IPRs). OSS challenges the traditional wisdom of the exclusive use of IPR, and is seen as a new IPR paradigm. So, at a first glance, it might not be clear, whether *protection of IPRs* and OSS have a positive or negative relationship. But at a second glance it becomes clear that *in practice* OSS rely on IPR-protection, mainly as this enables the enforcement of the OSS licenses that are an important formal institution of OSS.

It is true that some parts of the OSS movement, like for example the GPL-founder Richard Stallman, argue against intellectual property of software, although others oppose this.⁵ But nevertheless it is a matter of fact that the OSS licenses are “real” legal licenses, i.e. define the scope of transferred rights and are based on copyright law. Especially Stallman's GPL uses a so-called ‘Copyleft’-principle which ensures that the licensed software stays “open”. Basically this is achieved via restricting the alienation right, i.e. the right to redistribute, in the following way: Any further developed software as well as any derived work must be licensed as a whole under the GPL. Thus, here copyright is used to ensure that OSS stays OSS, the “GPL contains provisions covering property rights (...) [,] is based on copyright principles (...) [and] does not (...) remove copyright protection” (Gehring 2006, pp 62, 70). So OSS is not software without any property rights. In addition there exist a variety of different OSS licenses who differ in how they restrict the usage of the code. In particular firms ‘owning’ OSS projects make use of sophisticated licenses and dual-license strategies, as it is crucial for them to well-define

⁵ Some parts of the open source community argue in an “anti intellectual property”-way. The “Free Software Foundation” opposes the use of the term “intellectual property”, and its president Richard Stallman refuses the idea of intellectual property, arguing that because of moral reasons no one should be allowed to claim property rights on information or knowledge. This view is opposed by figure like Eric S. Raymond, co-founder of the Open Source Initiative. Raymond supports the idea of property right claims, and hence also of intellectual property rights, but simply argues that proprietary software (in the sense of closed source software) is simply an inefficient way of developing software (see Weber 2004). Others like e.g. Greg Perkins also point out that “Open Source depends on the idea of the individual human right to private property” (Perkins 1998).

what is exclusively owned and what not (for more details the different licenses see e.g. Lerner & Tirole 2005, for dual licenses see Välimäki 2003). Obviously, such legal arrangements are only possible and effective if intellectual property rights are respected and such licenses can be enforced.⁶ In addition to this, the OSS incentive and governance structures are based on trademarks: The so-called core developers of an OSS project control – thus manage – the project by using passive control rights that are their exclusive rights to decide whether to accept or reject contributions (von Engelhardt 2008, p 24, see also McGowan 2001, Wendel de Joode et al. 2003, p 20). These passive control rights are enforced by using the concept of ownership regarding the database in which the software is stored and the name – thus, the trademark – of the project. This prevents cloning of projects and supports the signaling function of the project's name, thus trademark. So again, OSS is based on IPRs. It is true that the principle of OSS minimizes the scope of exclusive usage of IPRs, IP-law respectively, and that the OSS licenses are inclusive (see von Engelhardt 2008), but nevertheless this principle of openness is protected using copyright law (e.g. see the GPL). Thus both, the non-commercial part of the OSS community as well as the firms involved, benefit in practice from the possibility to define and enforce IPRs. Hence protection of IPRs supports the formal institution “OSS licenses” as well as indirectly the governance structures and the informal institution 'reputation'. Therefore we state the following:

H7: The protection of intellectual property rights has a positive impact on the number of OSS developers or on OSS activity level.

Next we take into account the *degree of regulation* of economic activity. Thus, we analyze the impact of a set of formal institutions, the formal rules of regulation, on OSS development. We will argue that more regulation is not in favor of OSS development, and even hinders it. The main line of argument is that OSS has an entrepreneurial spirit. In general a high degree of regulation increases (transaction) costs of entrepreneurial activities and individual initiatives. This depresses such activities, and thus also OSS. Hence we measure a (set of) *formal institution(s)*, that has an *impact* on a *certain type of activities*. As OSS is part of this type of activities, we also expect an impact on OSS.

Being aware of the ambitious nature of OSS, one can distinguish two aspects of OSS that are linked to its entrepreneurial spirit: the culture of individual initiatives and OSS business models. Basically, OSS projects are set up or supported by individuals who see the need to develop code for different tasks. The principle of open code does not only imply the possibility to further develop the code, but it is also an expression of a culture to do so. Thus, rather than

⁶ See e.g. Kumar, 2006 on the GPL, for current examples of “the GPL in court” gpl-violations.org.

relying on big software companies to develop good software, there is a do-it-yourself spirit. If possible (i.e. if the user has the necessary abilities), users should fix bugs they discover and develop and implement new (missing) features. Thus in a sense the OSS development model relies on the idea to collect and coordinate individual initiatives. But beyond this, for many contributors OSS is simply a pragmatic solution, as they can individualize the code and further develop it if they need to. This is in particular of importance when it comes to the aspect of OSS business models. Thus OSS has an entrepreneurial spirit as it is based on the idea of individual initiatives and pragmatic problem solving. But additionally, the possibility to have access to and flexibly use the code (individualize, further develop etc.) enables entrepreneurial activities (in the economic sense), i.e. to run OSS business models. Hence OSS can be a precondition for start-ups etc. Clearly, strong regulation of economic activities in a country has a negative impact on doing business. Of course this is also true for OSS business models. Furthermore, in the long run strong regulations can also affect the attitudes of the inhabitants: the fact that they have learned that entrepreneurial activities and individual initiatives are costly and “not wanted” (thus regulated), should not only decrease the number of such activities but also the entrepreneurial spirit in general. Hence people living in a highly regulated environment are less likely think about and have ideas for starting individual initiatives.

So the theoretic argument is that entrepreneurial attitudes or spirit foster entrepreneurial activities. The “payoff” of such activities depends on regulation. Thus high regulation increases transaction costs and hence lowers the payoff. This finally leads to less entrepreneurial activities, and in the long run also to less entrepreneurial spirit. Because of its characteristics, OSS belongs to entrepreneurial activities, is based on entrepreneurial spirit respectively. Thus we should see a negative impact here:

H8: A high degree of intense economic regulation has a negative impact on the number of OSS developers as well as on the OSS activity level.

3 The Data

We draw our data from several sources. With respect to the institutional and cultural aspects we can make use of data available from different resources. With respect to the geographical location of the OSS developers we had to collect the data by our own. Nevertheless, whereas it is a relatively new approach to link institutional and cultural factors to the phenomena of OSS, there is already a literature describing the geographic origin of OSS developers. Basically there exist two approaches. Some studies are based on survey-data, for example Ghosh (2006), David et al (2003), and Ghosh et al. (2002). Other work, like Gonzalez-Barahona et al. (2008), Robles & Gonzalez-Barahona (2006), and Lancashire (2001), is based on specific data drawn

from code of certain OSS projects, mailing lists or informations from platforms like SourceForge.⁷ Regarding the data collection about the location of OSS developers, our paper belongs to the second branch.

3.1 Data about OSS Developers registered at SourceForge

SourceForge is the largest site hosting OSS projects.⁸ We draw our data about *OSS developers* registered at sourceforge.net from the SourceForge Research Data Archive (SRDA). SRDA is offered by the University of Notre Dame under a special agreement for scientific research. The database consists of dumps containing some of the information stored at the SourceForge webpage. The latest dumps with all information necessary for our analysis are those from 2006. Namely the dump of October 2006 is used to identify users. For activity level of users we can make use of the dumps from January 2006 until December 2006.

When OSS developers register at SourceForge they have to indicate a valid email address. Additionally, when registering developers can change the time zone from the default-value to their specific time zone (e.g. “Europe/Berlin”). Furthermore, the SRDA contains tables with the IP (internet Protocol address) of the users logged in, and also information about when and whether users posted messages. We are able to identify each user by the user-ID and connect this information with the indicated email address and time zone. Furthermore, we can connect each user to his or her IP, and we are also able to assign to each user the number of posted messages. The latter information is a proxy for the activity of an OSS developer.

The original data of the 2006 dumps delivers approximately 1.4 million datasets which have to be cleaned of all duplicates, fake accounts (like “nobody@nowhere.com”) and non reliable data. Then we assign to each user his or her geographical origin by making use of the email address, time-zone and IP. In particular we use the following *methods/indicators*:

- The first two indicators are assigned to the email address:
 - The first is the country coded Top-Level Domain (ccTLD) of the email address. Thus, the assumption is, that each user's ccTLD correctly indicates his or her native country (For example, “.us” for the USA, “.nl” for the Netherlands, or “.de” for Germany). A problem are so-called open ccTLDs, like “.ws” for Western Samoa. While ccTLDs limit registration to citizens or firms of their respective countries, in the case of “open” ccTLDs registration is possible (therefore “open”) to any interested registrant. The reason is that e.g. “.tv” (for Tuvalu) looks like “television”, or “.ws” (Western Samoa) looks like “website”. Therefore, one can make money by selling such accounts. However, this implies that such open ccTLDs can not be

⁷ Robles et al. (2001) provide a combination of both types of data collection.

⁸ See also the footnote on page 2.

used for geographical identification. In fact, these are “de facto” generic TLDs such as “.org” or “.com”. Therefore we exclude all open ccTLDs from the dataset when identifying via country coded Top-Level Domain of the email addresses.

- For all email accounts with generic TLDs it is possible to use information from the so-called second level domain (SLD). For example in case of “xyz@yahoo.com” is “yahoo” the SLD. It is possible to identify the location of the domain server of a SLD. Therefore we manually assign to each of the top 1000 SLDs their domain server, and therefore the country of the server. If one assumes that the location of the domain server of the SLD of a user's email address also indicates the country the user lives in, then it is possible to assign users with generic TLDs to countries. Clearly this method can be criticized as the probability of mistakes might be high. For example a Spanish developer using an yahoo.com email account would be counted as a citizen of the USA. We will come back to this later.
- Another indicator is the time zone indicated. Time zones like "EST" sum up several countries and can therefore not be used for the analysis. The same is true if 'time zone' has its default value, as it is not known whether the option time zone was just ignored, or not. Thus, members with the default or a summarizing time zone can not be geographically identified via this method. But nevertheless, well-defined and unique time zones can be used to assign a country to a user. For example, if one has chosen the time zone "Europe/Berlin", then this can be assigned to Germany. Clearly the assumption standing behind this is, that users report their time zone correctly (when changing it from the default value “CET”) and that this indicates their usual place of residence.
- Finally one can make use of the information offered by the saved IP, given that such information can be found in the SRDA. We use the partially available IPs of each user and calculate their actual habitation by GeoIP. GeoIP allows to identify geographic location of internet-connected devices via their IP-range. Namely the location of servers of internet service providers, Universities, etc, can easily be identified. Via these “providers”, the geographic location of internet users can be identified quite correctly.⁹ However, if unlucky, the IP belongs to a range that is assigned to regions but not to certain countries.

Identifying the geographical origin of OSS developers via ccTLD, IP and indicated time zone seems to be quite reliable because of theoretical reasons. In order to get an impression of the reliability we cross-check the results that ccTLD, IP and indicated time zone deliver. ccTLD and IP have a matching of 89.16%, IP and time zone deliver the same results in

⁹ To try out how exact this can be, simply visit <http://www.netip.de>.

87.29% of all cases, and time zone and ccTLD have 80.45%. As already mentioned above, identifying the location via SLD is from a theoretical point of view the weakest method. Thus, not surprisingly, checking IP with SLD, and time zone with SLD delivers matching rates of only 51.83%, and 56.45% respectively.

Therefore we combine all four methods in the following way: First, when possible, we identify users' geographical location via GeoIP. The remaining users are then identified via their ccTLD, if possible. The rest is then assigned to their country using the information about the time zone. The remaining 283,028 not located users are then assigned to a country using the information about the SLD. Doing so we end up with 1,315,263 users who are assigned to their countries (83,217 users, i.e. 6% could not be identified). However, as one might doubt the results using the SLD, we always run regressions with data containing the SLD-based identifications, and without.

As already mentioned, we are also able to extract the information whether and if, how often, a user posted a message in 2006. This is used as an indicator of activity. Therefore we are able to distinguish active developers (developers who had posted in 2006) from non-active ones. Furthermore, counting the number of messages posted by users from a country deliver us data about the OSS activity that comes from a specific country.

Weighting all these information by the number of inhabitants in 2006 (source: Worldbank), we finally end up with the following country-specific informations:

- Number of OSS developers per 1,000 inhabitants
- Number of active OSS developers per 1,000 inhabitants
- Level of OSS activity (Number of posted messages per 1,000 inhabitants)

As we have information about activity levels, our data offers more information about global OSS activities than any other non-survey data we are aware of. A graphical impression of the results are given by the “World Map of OSS Developers” (figure 3), the “World Map of Active OSS Developers” (figure 4), and the “World Map of OSS Activities” (figure 5).

--- [Figure 3 about here] ---

--- [Figure 4 about here] ---

--- [Figure 5 about here] ---

3.2 Data on GDP, Education and ICT

Obviously, the probability that a country's inhabitant becomes an OSS developer rises with the degree of economic and technical development, in the latter case mainly with the access to the internet. Thus, we have to control for this. Hence, we take into account the *GDP* per capita (purchasing power parity) for 2006 (“GDP2006”), data source is Worldbank (2007). Further-

more, we control for education, because (a) previous studies indicated that OSS developers are well-educated software engineers (or ICT students), and (b) in order to be able to write software code (i.e. programming) one must be able to think in abstract terms and logic. Additionally, most programming languages are based on English and the whole communication and coordination of OSS projects is done in English. As a measure for *education* we use the combined gross enrollment ratio for primary, secondary and tertiary schools with a four-year lag (EDUC2002, i.e. of the year 2002). The source is UNDP (2004).

In the above discussion we explained why we have to take aspects of *ICT* of the countries into account. However, worldwide data about e.g. the number of software developers, size of the software sector or other differentiated data about the ICT sector are poor. The best data available refer to internet access. Thus we use the number of internet users per 100 inhabitants (“InetUsers.per_100_inhab”) as a proxy here. The data for this come from the International Telecommunication Union (2006). At least for some countries, data about the share of employees working in the ICT sector is available. But as internet access is a precondition for OSS, we want to have this in our regression in any case. But with share of ICT employees *and* internet users we clearly run into problems of multicollinearity here: each internet access must have been installed by someone working in the ICT sector. Therefore we decided to leave this data out and use internet usage only.

3.3 Data on Cultural Factors and Social Capital

One main source for our analysis are the so-called “World Values Surveys”, that offer a wide range of country-specific cultural data and are often used in cross-cultural research. We make use of this for our variables about *cultural factors*. We use data from the waves of 1990, 1995/1998 and 1999/2000 in the form as one can receive them online (www.worldvaluessurvey.org, go to Online Data Analysis). However, not all questions were asked in all countries, and additionally not in all interviews. Thus we have to correct for that and eliminate all those with too little overall coverage.¹⁰ Some of the questions have a scale for the possible answer (like e.g. 1 = strongly disagree, up to 10 = strongly agree). Although it is very common to use the mean of such answers, this is quite critical from a methodological point of view, as in such a case one treats ordinal scaled data like being on an interval scale. It is better to choose a certain threshold, i.e. for example count the percentage of answers with scale 4 or smaller. As we want to be able to distinguish groups (here countries) from each other with respect to a certain characteristics, a good way to find such a threshold is to “ask the data”. Thus, we look at the

¹⁰ In case of questions that were not asked in 100% of all interviews in a country (but with a sufficient high percentage) we additionally have to correct the percentage of answers, as the numbers one receives from the WVS online-dataset always sum up with the “not asked”- share to 100%.

direction the answers point to, choose those of interest, and then set different plausible thresholds. In a next step we compare the variance, and choose c.p. those with the higher variance, as this is an indication by the data that we made the right cut in order to measure the difference of the respective category. (If variances were close to each other, we choose those threshold with the distribution closer to the normal distribution). However, whenever we refer to WVS data henceforth, they were, if necessary, treated in the way just described.

3.3.1 Social Capital: Interpersonal Trust

With respect to *interpersonal trust*, we make use of the data offered by the World Values Survey regarding social, or: interpersonal, trust. Interpersonal trust is measured by the average percentage of respondents saying ‘most people can be trusted’. (The question is “Generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?” Possible answers are either “Most people can be trusted”, or “Can’t be too careful”). We label this variable as “IntPer_Trust”.

3.3.2 Degree of Individualism/Self-Determination

As already mentioned before, a cultural dimension of interest is *individualism/self-determination*. The term 'Individualism' refers here to a famous category in cross-cultural studies. Hofstede's individualism „pertains to societies in which the ties between individuals are loose: everyone is expected to look after himself or herself and his or her immediate family“ (Hofstede 1991 p 52). Hofstede developed the individualism index for 50 countries based on a world-wide survey of IBM employees that was carried out during 1978-83. The questions the individualism index was build upon asked about whether the job leaves sufficient time for personal and family life, considerable freedom to adopt own approaches, includes challenging work, offers opportunities to improve and learn new skills, etc. (Hofstede 1991, p 49 ff). Hence, based on these categories, high scores in individualism indicate the prevalence of individual interest in a society, i.e. in a sense that people would like (and can) “do what they want to do”. However, we use an individualism measure developed and used by Diener, Gohm, Oishi, Suh, and Triandis. Basically, this is an updated and further developed version of Hofstede's measure (namely a merge of ratings provided by Triandis and Hofstede's scores, see e.g. Suh et al. 1998, p 485). We collect the values for this measure from Diener et al. (2000), Oishi (2000), and Suh et al. (1998).

Obviously the concept of ‘Individualism’ in the tradition of Hofstede's definition should correlate with leisure time preferences, preferences for independence and self responsibility etc. Here we can again make use of the WVS data. Treating the data as described above lead

to the following categories for “leisure time” and “self-responsibility”:

- Leisure time: % of all respondents of a country saying “1 Very important” (WVS-Question was asking about how important leisure time is in ones life)
- Self-responsibility: % of all respondents of a country ranging from 1 to 4. (WVS Question was asking to put oneself on a range 1 to 10 expression own opinion, with 1 = People should take more responsibility to provide for themselves, vs 10 = The government should take more responsibility to ensure that everyone is provided for.)

Additionally, the WVS data delivers the percentage of all respondents of a country who mentioned that “Feeling of responsibility” is an important quality children should learn at home. (They were given a list of qualities that children can be encouraged to learn at home. They should choose up to five they consider to be especially important.).

For our analysis, we want to have one measure for the degree of *individualism/self-determination*. Therefore we make use of a tool that is widely used in cultural studies: the so-called principal component analysis. The idea of this multivariate statistical technique is the following: Assumed a (or more) certain characteristic(s) (e.g. "culture") can not be measured directly, but one has several indicators for this characteristic(s). Then the principal component analysis (PCA) is a useful tool to identify the meaningful underlying variable(s) and construct this based on the data available. In other words, the PCA tries to find components that explain the maximum amount of variance. Thus the goals of a PCA is to reduce the dimension of the data and to detect structure in the relationships between variables, that is to classify variables. Therefore one takes a set of variables of whom one expects a relationship because of theoretical reasons (e.g. as one sees them as expressions of the same attitude), and then runs the PCA, that is minimize the sum of the squared perpendicular distances to the axis of the principal component. We do so, and finally construct a PCA-component labeled “SelfDet_Indiv”, that consists of the individualism scores mentioned above, “leisure time”, “self-responsibility” and whether a child should learn responsibility. “SelfDet_Indiv” has a Kaiser-Meyer-Olkin measure of sampling adequacy of 0.683.

3.3.3 Attitudes Toward Competition and the Merit Principle

For the degree of positive attitudes toward *competition and/or the merit principle* we are also able to construct a PCA based component, labeled “Comp_Merit” consisting of variables from the WVS, measuring attitudes towards income differences as incentives, whether competition is perceived as good or harmful, and the importance to teach a child independence:

- Income differences as incentives: % of respondents of a country ranging from 10 to 7 regarding "Incomes should be made more equal vs We need larger income differences

as incentives" (The WVS question was asking to put oneself on a range 1 to 10 expression own opinion, with 1 = Incomes should be made more equal, vs 10 = We need larger income differences as incentives.)

- Competition is good: % of respondents of a country ranging from 1 to 2 (Question asked to range oneself according to opinion about "Competition is good, it stimulates people to work hard and develop new ideas, vs. Competition is harmful, It brings the worst in people. Range: 1 = Competition is good, 10 = Competition is harmful.)
- Importance to teach a child independence: % of all respondents of a country who mentioned that "Independence" is an important quality children should learn at home. (They were given a list of qualities that children can be encouraged to learn at home. They should choose up to five they consider to be especially important.)

However, the PCA based component "Comp_Merit" might be problematic, as it has a Kaiser-Meyer-Olkin measure of sampling adequacy of 0.517. Therefore we run regression with and without "Comp_Merit".¹¹

3.3.4 Data on Attitudes towards Novelty (New Ideas and Scientific Progress)

Data on attitudes towards novelty, i.e. a preference for new ideas and scientific progress also come from the 1990, 1995/1998 and 1999/2000 waves of the World Values Survey. We make use of the following:

- "Pref_New_Ideas" is the % of all respondents of a country preferring new ideas over old ones by ranging from 8 to 10. (The survey question asks to rate oneself on a scale about "Ideas stood test of time better vs New ideas better", with 1 = Ideas that stood test of time are generally best, up to 10 = New ideas are generally better than old ones.)
- "ScienAdvan_Will_help" is the % of all respondents of a country saying that scientific advances we are making will help mankind. (The question is "In the long run, do you think the scientific advances we are making will help or harm mankind?" Possible answers: 1 Will help, 2 Will harm, 3 Some of each.)

3.4 Data on IPR Protection and Regulation

In order to evaluate the degree of regulation, we use the data offered with the Economic Freedom of the World Index (Gwartney et al. 2008). The report offers an inverse index of regulation, called "Area 5: Regulation of Credit, Labor, and Business". We use this index in order to measure the degree of regulation in a society in 2006, and denote this variable by "Regulation2006". This index is build upon several sub-indices measuring credit market regulations,

¹¹ We also run regression with "Competition is a good thing" only. However the results were quite similar, therefore we did not put them into this paper.

labor market regulations, and business regulations (Gwartney et al. 2008, p 189ff).

With respect to IPR, we use of one of the sub-indices of Gwartney et al. (2006) belonging to the *property right* section: the sub-index of the protection IPR (“2C Protection of intellectual property”) for the year 2004, the latest IPR-data available. This IPR sub-index is based on data from the The Global Competitiveness Report of the World Economic Forum.¹² We denote this index by “IPR_Protection2004”. Another measure related to IPR are the figures about the software piracy rates in 2006, taken from the Fifth Global Software Piracy Study (Business Software Alliance 2007).

4. Empirical Results

This section is dedicated to the presentation and discussion of the empirical results. To test hypotheses H1 through H8, we run linear regression models (OLS) based on our hypotheses. We run different models, varying the endogenous variable as well as the set of explanatory variables. The results appear quite robust and are displayed in tables 1 through 3. All three tables are structured as follows: After the control variables, the influence of the variables presenting hypotheses H1 through H8 is shown. We present the three most representative models, each with (for each table equations 1, 3 and 5 respectively) and without “Comp_Merit”. Social trust, internet users and IPR¹³ is used across the board, other variables are skipped in single equations. We are able run regressions with up to 70 countries, and we are able to distinguish with respect to the level of contribution.

Table 1 presents the regression results for model 1, using the number of OSS developers per 1,000 inhabitants including those localized using the information about the SLD. We analyze three sub-models. In the Appendix the reader can find the same regressions for OSS developers data *without* those localized using the information about the SLD. In a second model, we run regressions for the active OSS developers per 1,000 inhabitants, again including those localized using the information about the SLD (for results *without* SLD see Appendix). Finally, we analyze the OSS activity level, as usual here we present the results with those located via SLD (for the other version see Appendix).

¹² The question was whether “Intellectual property protection in your country is 1 = weak and not enforced, up to 7 = strong and enforced”.

¹³ We also run regression with “PiracyRates2004”. The results were basically the same, beside the fact that regulation was no longer significant, and – more important – “PiracyRates2004” itself was *never* significant.

Table 1: *Dependent Variable: OSS Developers per 1,000 inhabitants (with SLD)*

Equation	1.1	1.2	1.3	1.4	1.5	1.6
(Intercept)	-1,93e+003*** (0.00403)	-1,91e+003*** (0.00363)	-1,09e+003** (0.0255)	-9,59e+002** (0.0421)	-1,16e+003** (0.026075)	-1,15e+003** (0.023850)
<i>Control Variables:</i>						
GDP2006	-4,21e-003 (0.64485)	-3,89e-003 (0.66160)	9,82e-003 (0.1757)	8,27e-003 (0.2459)	-4,45e-003 (0.634357)	-4,30e-003 (0.636556)
Educ2002	1,98e+000 (0.67257)	2,00e+000 (0.66737)	3,12e+000 (0.4771)	2,30e+000 (0.5955)	5,57e-001 (0.906606)	5,67e-001 (0.903977)
<i>Explaining Variables:</i>						
InetUsers.per_100_inhab.	1,37e+001*** (0.00213)	1,37e+001*** (0.00194)	1,02e+001** (0.0150)	1,01e+001** (0.0161)	1,54e+001*** (0.000673)	1,54e+001*** (0.000595)
Pref_New_Ideas	1,68e+002 (0.69915)	1,52e+002 (0.71943)			6,58e+001 (0.881925)	5,84e+001 (0.891947)
ScienAdvan_Will_help	1,25e+003*** (0.00672)	1,22e+003*** (0.00390)			1,17e+003** (0.012603)	1,15e+003*** (0.007141)
SelfDet_Indiv	1,17e+002** (0.01395)	1,15e+002** (0.01210)	5,73e+001 (0.1631)	6,85e+001* (0.0872)	1,23e+002** (0.011507)	1,22e+002*** (0.009142)
IntPer_Trust	1,17e+003** (0.01171)	1,17e+003** (0.01029)	6,50e+002* (0.0950)	5,92e+002 (0.1250)	1,16e+003** (0.014211)	1,17e+003** (0.012804)
Comp_Merit	-6,76e+000 (0.84849)		3,37e+001 (0.2587)		-3,10e+000 (0.931688)	
IPR_Protection2004	3,73e+001 (0.40249)	3,76e+001 (0.39493)	3,68e+001 (0.3712)	3,56e+001 (0.3881)	5,12e+001 (0.257374)	5,13e+001 (0.251981)
Regulation2006	1,05e+002* (0.06442)	1,04e+002* (0.06286)	8,52e+001 (0.1243)	8,28e+001 (0.1359)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.8147	0.8183	0.7845	0.7835	0.8052	809
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

Table 2: *Dependent Variable: Active Developers per 1,000 inhabitants (with SLD)*

Equation	2.1	2.2	2.3	2.4	2.5	2.6
(Intercept)	-4,23e+002*** (0.00266)	-4,24e+002*** (0.00213)	-2,45e+002** (0.0171)	-2,14e+002** (0.0330)	-2,43e+002** (0.02701)	-2,45e+002** (0.02271)
<i>Control Variables:</i>						
GDP2006	-1,36e-003 (0.47665)	-1,37e-003 (0.46059)	2,82e-003* (0.0671)	2,43e-003 (0.1090)	-1,42e-003 (0.47329)	-1,47e-003 (0.44481)
Educ2002	4,99e-001 (0.61053)	4,99e-001 (0.60722)	5,35e-001 (0.5633)	3,30e-001 (0.7194)	1,66e-001 (0.86826)	1,62e-001 (0.86978)
<i>Explaining Variables:</i>						
InetUsers.per_100_inhab.	2,43e+000*** (0.00820)	2,44e+000*** (0.00752)	1,81e+000** (0.0388)	1,79e+000** (0.0424)	2,82e+000*** (0.00268)	2,83e+000*** (0.00237)
Pref_New_Ideas	4,20e+001 (0.64402)	4,27e+001 (0.62869)			1,81e+001 (0.84644)	2,07e+001 (0.81925)
ScienAdvan_Will_help	2,15e+002** (0.02435)	2,16e+002** (0.01322)			1,95e+002** (0.04553)	2,01e+002** (0.02475)
SelfDet_Indiv	2,70e+001*** (0.00679)	2,71e+001*** (0.00484)	1,28e+001 (0.1389)	1,57e+001* (0.0658)	2,85e+001*** (0.00577)	2,88e+001*** (0.00372)
IntPer_Trust	2,59e+002*** (0.00755)	2,59e+002*** (0.00685)	1,21e+002 (0.1383)	1,07e+002 (0.1897)	2,58e+002*** (0.00993)	2,57e+002*** (0.00931)
Comp_Merit	2,65e-001 (0.97136)		8,42e+000 (0.1814)		1,12e+000 (0.88331)	
IPR_Protection2004	1,47e+001 (0.11857)	1,47e+001 (0.11493)	1,15e+001 (0.1854)	1,12e+001 (0.1998)	1,79e+001* (0.06289)	1,79e+001* (0.06064)
Regulation2006	2,45e+001** (0.03925)	2,45e+001** (0.03684)	2,02e+001* (0.0845)	1,96e+001* (0.0960)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.8288	0.8322	0.8019	0.7992	0.8169	0.8204
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

Table 3: *Dependent Variable: OSS Activity Level (Messages per 1,000 inhabitants, with SLD)*

Equation	3.1	3.2	3.3	3.4	3.5	3.6
(Intercept)	-2,97e+004*** (0.004832)	-2,94e+004*** (0.004299)	-1,65e+004** (0.0361)	-1,44e+004* (0.05951)	-1,84e+004** (0.024127)	-1,83e+004** (0.021781)
<i>Control Variables:</i>						
GDP2006	-1,70e-001 (0.239417)	-1,66e-001 (0.238119)	2,54e-001** (0.0327)	2,29e-001* (0.05040)	-1,73e-001 (0.239166)	-1,72e-001 (0.230762)
Educ2002	5,71e+001 (0.439204)	5,73e+001 (0.433200)	4,71e+001 (0.5088)	3,36e+001 (0.63387)	3,63e+001 (0.625250)	3,64e+001 (0.620679)
<i>Explaining Variables:</i>						
InetUsers.per_100_in- hab.	1,59e+002** (0.020553)	1,59e+002** (0.019484)	1,18e+002* (0.0784)	1,16e+002* (0.08277)	1,83e+002*** (0.007959)	1,83e+002*** (0.007356)
Pref_New_Ideas	3,76e+003 (0.582851)	3,55e+003 (0.593131)			2,26e+003 (0.744180)	2,18e+003 (0.745654)
ScienAdvan_Will_help	1,25e+004* (0.077820)	1,21e+004* (0.061658)			1,13e+004 (0.116069)	1,11e+004* (0.089693)
SelfDet_Indiv	2,77e+003*** (0.000346)	2,74e+003*** (0.000236)	1,56e+003** (0.0209)	1,75e+003*** (0.00824)	2,86e+003*** (0.000287)	2,85e+003*** (0.000176)
IntPer_Trust	2,66e+004*** (0.000398)	2,67e+004*** (0.000324)	1,35e+004** (0.0343)	1,25e+004** (0.04728)	2,65e+004*** (0.000518)	2,66e+004*** (0.000433)
Comp_Merit	-8,63e+001 (0.876493)		5,56e+002 (0.2504)		-3,29e+001 (0.953662)	
IPR_Protection2004	1,02e+003 (0.148537)	1,02e+003 (0.143294)	5,31e+002 (0.4267)	5,11e+002 (0.44538)	1,22e+003* (0.086485)	1,22e+003* (0.083162)
Regulation2006	1,53e+003* (0.084356)	1,53e+003* (0.082292)	1,23e+003 (0.1694)	1,19e+003 (0.18452)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.8422	0.8453	809	808	0.8356	0.8388
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

5. Comparison and interpretation of the results

In this section we compare and interpret the results of the different models. The control variables do not contribute to the explanation of OSS activities. The evidence for the other variables is mixed.

H1: ICT is beneficial both for the number of OSS developers and the OSS activity level.

The number of internet users is positively correlated with OSS activities and highly significant. As already mentioned, this can be interpreted from both a demand and a supply perspective. The higher the number of users, the higher the number of potential software producers seems to be – thus the supply channel. At the same time, a higher number of internet users can be seen as a proxy for the potential market size for OS business models, hence demand.

H2: A preference for new ideas has a positive impact on the number of OSS developers as well as on the OSS activity level.

Surprisingly “Pref_New_Ideas” is positively but not significantly correlated with OSS activities. Thus, country-wide openness to new ideas is not encouraging participation in OSS. Interestingly, this is different with respect to the attitude towards scientific progress:

H3: A positive attitude towards scientific progress has a positive impact on the number of OSS developers and on the level of OSS activities.

A positive attitude towards scientific progress is clearly significant with respect to the number of developers. It is also significant with respect to active developers, and the activity level.

The preferences for new ideas and the attitude towards scientific progress measure different aspects (someone who likes new ideas can still be skeptical about the impact of scientific progress). Nevertheless one might expect, that it is the combination of both that is beneficial for OSS. The argument would be that openness to new ideas has to meet a preference for scientific aspects in order to fit into the OSS community. Therefore, we also run regressions with an interaction term, but this was never significant.

H4: the degree of individualism/self-determination of a society has a positive impact on the number of OSS developers as well as on the OSS activity level.

As for hypotheses 4, stating that the degree self-determination of a society has a positive impact on the number of OSS developers as well as on the OSS activity level, the number of OSS

developers at SourceForge is indeed positively correlated with the degree of individualism. Interestingly the significance level rises when it comes to the *active* developers (table 2), and even more, when one looks at the activity level (table 3). This fits our expectations. The way of software production of OSS is often characterized as collective. At the same time however, the OSS contributors are volunteers, and no one can force them (i.e. command and control like in firms) to do certain things. Hence, those individuals voluntarily participate in an OSS project when they want, and in the way they want. In other words, being an (active) OSS developer can be a way of individualistic self-fulfillment. Therefore, it is highly plausible that societies with high account of self-determination are experiencing a higher OSS activity level.

H5: Social Capital in terms of interpersonal trust has a positive impact on the number of OSS developers as well as on the OSS activity level.

The number of OSS developers is positively correlated with the degree of interpersonal trust. Therefore H5 is not rejected. This fits our expectations. Again, despite the fact that this variable is highly significant throughout all equations, it is interesting to notice that this factor is more significant when it is about the active developers, the activity level respectively. In a society generating mutual trust, private provision of public goods indeed seems more likely.

H6: A culture of positive attitudes toward competition and the merit principle has a positive impact on the number of OSS developers as well as on the OSS activity level.

The PCA component “Comp_Merit” was never significant (nor was the positive attitude towards competition solely). Therefore H6 has to be rejected. A possible explanation could be that individualistic self-fulfillment aspects and self-determination are more important on the level of culture.

H7: The protection of intellectual property rights has a positive impact on the number of OSS developers or on OSS activity level.

In regressions without the regulation measure, the number of active OSS developers and the level of activity both are positively correlated with the degree of protection of intellectual property rights. Hence, H7 cannot be rejected. It seems that indeed OSS also relies on the security of intellectual property rights. This is plausible if one remembers that, as already mentioned, OSS licenses are built upon copyright law. OSS relies on the idea of intellectual property rights, although it uses this institution in a “new” way. The deny of intellectual property rights as such might even harm OSS, as then for example Stallman's GPL could not be en-

forced anymore. We are aware of the fact that the reader might have a possible second explanation in mind. Typically the argument goes as follows: In societies with a low de facto protection of IPRs there is not so much “need” for OSS, as one can get software for free (or at least at low costs) anyway. This shall explain why we have more OSS contribution when IPR protection is strong. Hence, in some sense, this argument sees OSS as a substitute for pirated software. However, this explanation is not convincing because of various reasons. Beside the fact that we analyze the production side of OSS (developers and activity level) not the demand side, there are two main counter-arguments: First, if OSS is a substitute for piracy software we should see an effect of piracy rates. But – as already mentioned in footnote 13 – piracy rates are never significant. Second, OSS is far more than just “cheap” software: the key element of OSS is that one has access to the source code and can thus further develop it and so on. But a pirated copy of a proprietary software (closed source software) is still just a copy of the binary code. Whereas the source code is the human-readable recipe of a software, the binary code is not readable by humans. Thus piracy software can not be a substitute for OSS as it is missing the source code.

H8: A high degree of intense economic regulation has a negative impact on the number of OSS developers as well as on the OSS activity level.

In some regressions, the inverse measure of regulation had a positive sign and was significant. Thus H8 cannot be rejected. Hence, one could conclude that OSS activities depend on regulations, exactly as other entrepreneurial activities and individual initiatives are positively correlated with lower regulation, i.e. a set of reasonable regulations.

Again one might think about to run regressions with interaction terms. The reason is the following. Positive attitudes toward competition and the merit principle, protection of IPRs, and less regulation are all aspects that relate to OSS and OS business models. One might argue that it is precisely the combination of less regulation and a sense for competition, or less regulation and good IPR protection, or even the combination of the three, that is in favor of business and thus also of OS business models. This could then affect the OSS activities as well. Therefore we also run regressions with such interaction terms. The results are clear: only the interaction term of IPR protection and regulation is significant (positively) in some regressions. It has an impact only if we examined the activity level and the active developers. However, the main message is here, that this also supports our recent hypotheses.

6 Summary

The paper presents a cross-country study of how the (relative) number of OSS developers per inhabitants and the OSS activities of a country depend on institutional and cultural factors that belong to level one and two of Williamson's framework. For this purpose we break up the phenomena OSS into several elements, identifying more general, underlying aspects. We then connect these aspects with the institutional or cultural factors. Based on the impact of the particular institutional or cultural factor on the particular aspect, we can conclude about the impact on OSS. In detail we have examples of the impact of culture in terms of values and preferences and in forms of beliefs, and of how culture can foster or hinder the implementation and/or functioning of institutions. In addition we have examples of how formal 'level two'-institutions have an impact on the functioning of lower-level formal and informal institutions (IPR protection) and on the outcome, thus payoffs, of certain activities.

We can assign 1.3 m. OSS developers from SourceForge to their countries, that are 94% of the total at SourceForge in 2006. With the posted messages we have a proxy for the activity of each developer. We are able to run regressions with about 70 countries, as the data about the cultural and institutional variables are not available for all the countries existing.

Beside the fact that internet access is an important factor, our findings regarding cultural and institutional aspects are the following: A positive attitude towards scientific progress as well as a culture of self-determination/individualism is in favor of OSS. The same is true for interpersonal trust. IPR protection is significant only in some regressions, but when, then it has positive sign. And finally less market regulation fosters OSS.

Our analysis shows that the non-equal geographical distribution of OSS activities is not only driven by aspects like GDP, education or internet. It can be explained by the differences in several cultural and institutional factors, and thus underlines the importance of these factors. Hence this study shows the impact of such factors on micro(economic) behavior, using the case of OSS development as an (special) example. This can help to better understand the role such cultural institutional factors play. But it also improves the understanding of the phenomena OSS. Our findings support a view of OSS as being an entrepreneurial activity that relies on trust as well as on IPR protection. It has a strong individualistic/self-deterministic aspect, combined with a spirit of individual initiatives. The fact that OS can be also (the basis of a) business model is also supported by our findings, as the results for less market regulation and IPR protection show.

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Appendix

Table 4: *Dependent Variable: OSS Developers per 1,000 inhabitants (without SLD)*

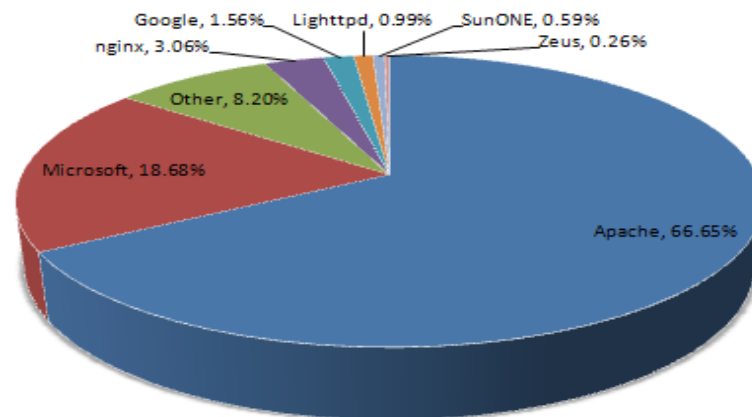
Equation	4.1	4.2	4.3	4.4	4.5	4.6
(Intercept)	-1,84e+003*** (0.00781)	-1,81e+003*** (0.00775)	-1,05e+003** (0.0346)	-9,53e+002** (0.0479)	-1,10e+003** (0.041180)	-1,08e+003** (0.04076)
<i>Control Variables</i>						
GDP2006	-7,77e-003 (0.41305)	-7,15e-003 (0.43970)	8,43e-003 (0.2564)	7,21e-003 (0.3212)	-8,01e-003 (0.408647)	-7,55e-003 (0.42388)
Educ2002	2,32e+000 (0.63414)	2,35e+000 (0.62717)	3,17e+000 (0.4821)	2,53e+000 (0.5689)	9,38e-001 (0.848501)	9,69e-001 (0.84203)
<i>Explaining Variables:</i>						
InetUsers.per_100_inhab.	1,42e+001*** (0.00221)	1,42e+001*** (0.00207)	1,07e+001** (0.0127)	1,06e+001** (0.0130)	1,58e+001*** (0.000724)	1,58e+001*** (0.00066)
Pref_New_Ideas	2,05e+002 (0.65094)	1,72e+002 (0.69505)			1,05e+002 (0.818084)	8,23e+001 (0.85336)
ScienAdvan_Will_help	1,10e+003** (0.02026)	1,04e+003** (0.01670)			1,02e+003** (0.033401)	9,74e+002** (0.02640)
SelfDet_Indiv	1,13e+002** (0.02197)	1,08e+002** (0.02180)	4,76e+001 (0.2573)	5,64e+001 (0.1664)	1,19e+002** (0.018013)	1,15e+002** (0.01653)
IntPer_Trust	1,18e+003** (0.01377)	1,20e+003** (0.01183)	5,87e+002 (0.1403)	5,42e+002 (0.1683)	1,18e+003** (0.016124)	1,19e+003** (0.01414)
Comp_Merit	-1,33e+001 (0.71750)		2,64e+001 (0.3874)		-9,76e+000 (0.794477)	
IPR_Protection2004	3,17e+001 (0.49339)	3,21e+001 (0.48347)	3,09e+001 (0.4644)	2,99e+001 (0.4772)	4,51e+001 (0.333479)	4,54e+001 (0.32669)
Regulation2006	1,02e+002* (0.08370)	1,00e+002* (0.08391)	8,35e+001 (0.1419)	8,16e+001 (0.1500)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.7859	0.7896	0.7585	0.7596	0.7768	0.7809
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

Table 5: *Dependent Variable: Active Developers per 1,000 inhabitants (without SLD)*

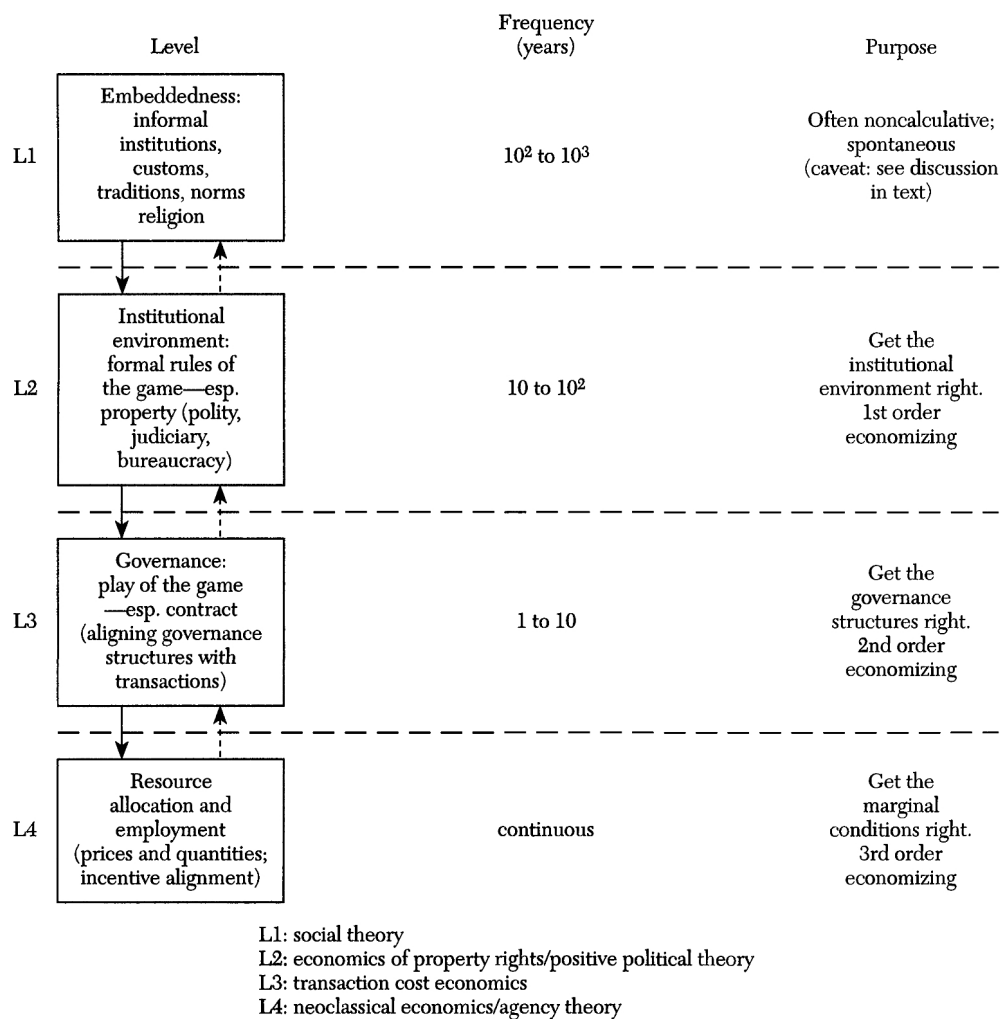
Equation	5.1	5.2	5.3	5.4	5.5	5.6
(Intercept)	-4,10e+002*** (0.00445)	-4,08e+002*** (0.00388)	-2,40e+002** (0.0226)	-2,13e+002** (0.0372)	-2,35e+002** (0.03616)	-2,35e+002** (0.03251)
<i>Control Variables:</i>						
GDP2006	-1,96e-003 (0.31883)	-1,92e-003 (0.31629)	2,60e-003 (0.1001)	2,26e-003 (0.1442)	-2,02e-003 (0.31930)	-2,02e-003 (0.30704)
Educ2002	5,78e-001 (0.56709)	5,80e-001 (0.56191)	5,63e-001 (0.5542)	3,88e-001 (0.6803)	2,54e-001 (0.80427)	2,54e-001 (0.80212)
<i>Explaining Variables:</i>						
InetUsers.per_100_inhab.	2,52e+000*** (0.00793)	2,52e+000*** (0.00736)	1,90e+000** (0.0348)	1,88e+000** (0.0368)	2,90e+000*** (0.00266)	2,90e+000*** (0.00239)
Pref_New_Ideas	4,95e+001 (0.59752)	4,73e+001 (0.60307)			2,62e+001 (0.78423)	2,60e+001 (0.77940)
ScienAdvan_Will_help	1,91e+002* (0.05063)	1,86e+002** (0.03636)			1,72e+002* (0.08448)	1,71e+002* (0.05944)
SelfDet_Indiv	2,64e+001*** (0.00997)	2,61e+001*** (0.00807)	1,12e+001 (0.2060)	1,37e+001 (0.1153)	2,78e+001*** (0.00831)	2,78e+001*** (0.00613)
IntPer_Trust	2,67e+002*** (0.00764)	2,68e+002*** (0.00673)	1,14e+002 (0.1734)	1,02e+002 (0.2209)	2,66e+002*** (0.00972)	2,66e+002*** (0.00881)
Comp_Merit	-9,00e-001 (0.90580)		7,21e+000 (0.2643)		-6,99e-002 (0.99286)	
IPR_Protection2004	1,35e+001 (0.16195)	1,35e+001 (0.15672)	1,04e+001 (0.2461)	1,01e+001 (0.2588)	1,67e+001* (0.09061)	1,67e+001* (0.08734)
Regulation2006	2,38e+001 (0.05119)	2,37e+001** (0.04927)	1,98e+001* (0.1000)	1,93e+001 (0.1095)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.8288	0.8322	0.8019	0.7992	0.8169	0.8204
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

Table 6: *Dependent Variable: OSS Activity Level (Messages per 1,000 inhabitants) (without SLD)*

Equation	5.1	5.2	5.3	5.4	5.5	5.6
(Intercept)	-2.901e+01*** (0.006123)	-2.867e+01*** (0.005653)	-1.624e+01** (0.0411)	-1,43e+004* (0.0634)	-1,79e+004** (0.028580)	-1,78e+004** (0.026605)**
<i>Control Variables:</i>						
GDP2006	-1.943e-04 (0.181879)	-1.885e-04 (0.183376)	2,45e-001** (0.0419)	* 2,21e-001 (0.0607)	-1,98e-001 (0.182253)	-1,94e-001 (0.177955)
Educ2002	5.897e-02 (0.428243)	5.922e-02 (0.421764)	4,72e+001 (0.5125)	3,48e+001 (0.6248)	3,85e+001 (0.606626)	3,87e+001 (0.600836)
<i>Explaining Variables:</i>						
InetUsers.per_100_inhab.	1.630e-01** (0.018586)	1.626e-01** (0.017694)	1,22e+002* (0.0718)	1,21e+002* (0.0750)	1,87e+002*** (0.007230)	1,87e+002*** (0.006725)
Pref_New_Ideas	4.012e+00 (0.560732)	3.711e+00 (0.579250)			2,54e+003 (0.715449)	2,37e+003 (0.725953)
ScienAdvan_Will_help	1.148e+01 (0.107685)	1.087e+01 (0.094527)			1,03e+004 (0.154491)	9,93e+003 (0.131539)
SelfDet_Indiv	2.741e+00*** (0.000423)	2.702e+00*** (0.000308)	1,50e+003** (0.0281)	1,67e+003** (0.0122)	2,83e+003*** (0.000348)	2,81e+003*** (0.000229)
IntPer_Trust	2.676e+01*** (0.000410)	2.688e+01*** (0.000329)	1,31e+004** (0.0421)	1,22e+004* (0.0554)	2,67e+004*** (0.000523)	2,67e+004*** (0.000431)
Comp_Merit	-1.233e-01 (0.825601)		5,11e+002 (0.2960)		-7,09e+001 (0.900988)	
IPR_Protection2004	9.801e-01 (0.167415)	9.842e-01 (0.161472)	4,92e+002 (0.4662)	4,73e+002 (0.4832)	1,18e+003* (0.099634)	1,18e+003* (0.095864)
Regulation2006	1.505e+00* (0.092253)	1.494e+00* (0.090866)	1,22e+003 (0.1798)	1,18e+003 (0.1933)		
D. of Freedom	49	50	61	62	50	51
Adjusted R ²	0.8089	0.8126	0.7814	0.7805	0.7974	0.8014
The values in brackets are the p-values. Significance levels are denoted by *** = 99%, ** = 95%, and * = 90%.						

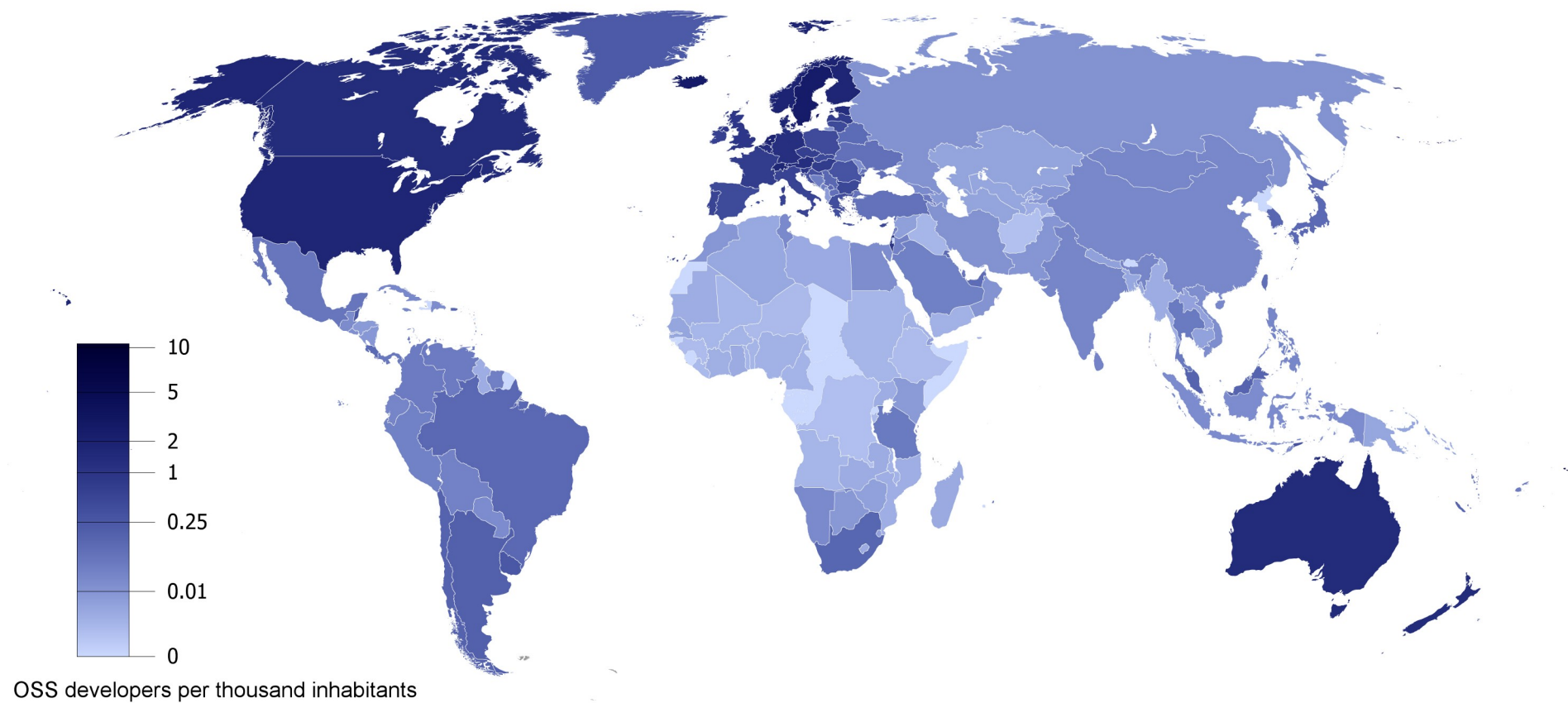
Figure 1: Server Share amongst the Million Busiest Sites, March 2009

(Source: Netcraft's March 2009 Web Server Survey, www.netcraft.com)

Figure 2: Williamson's four interrelated levels of social and institutional analysis*Figure 1. Economics of Institutions*

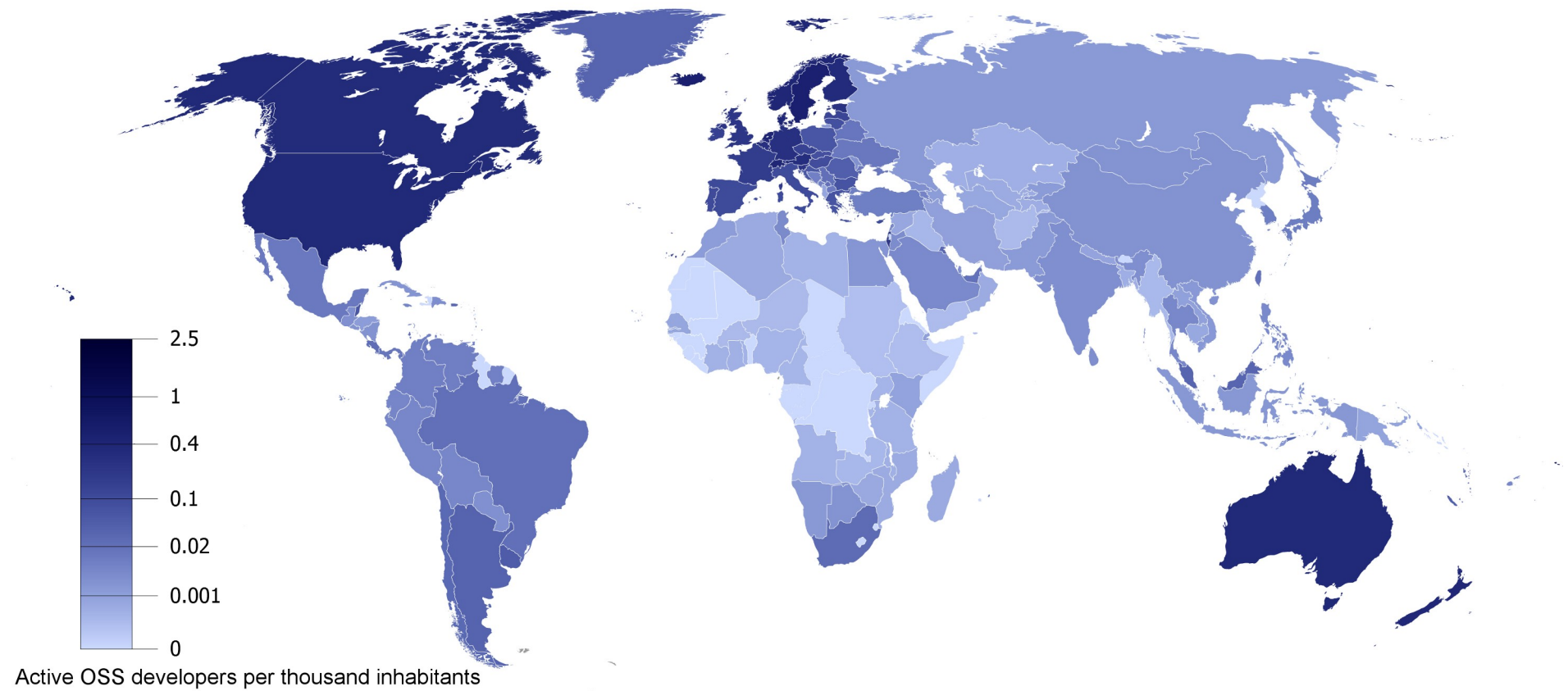
(Source: Williamson 2000, p 597)

Figure 3: World Map of OSS Developers (per thousand inhabitants)



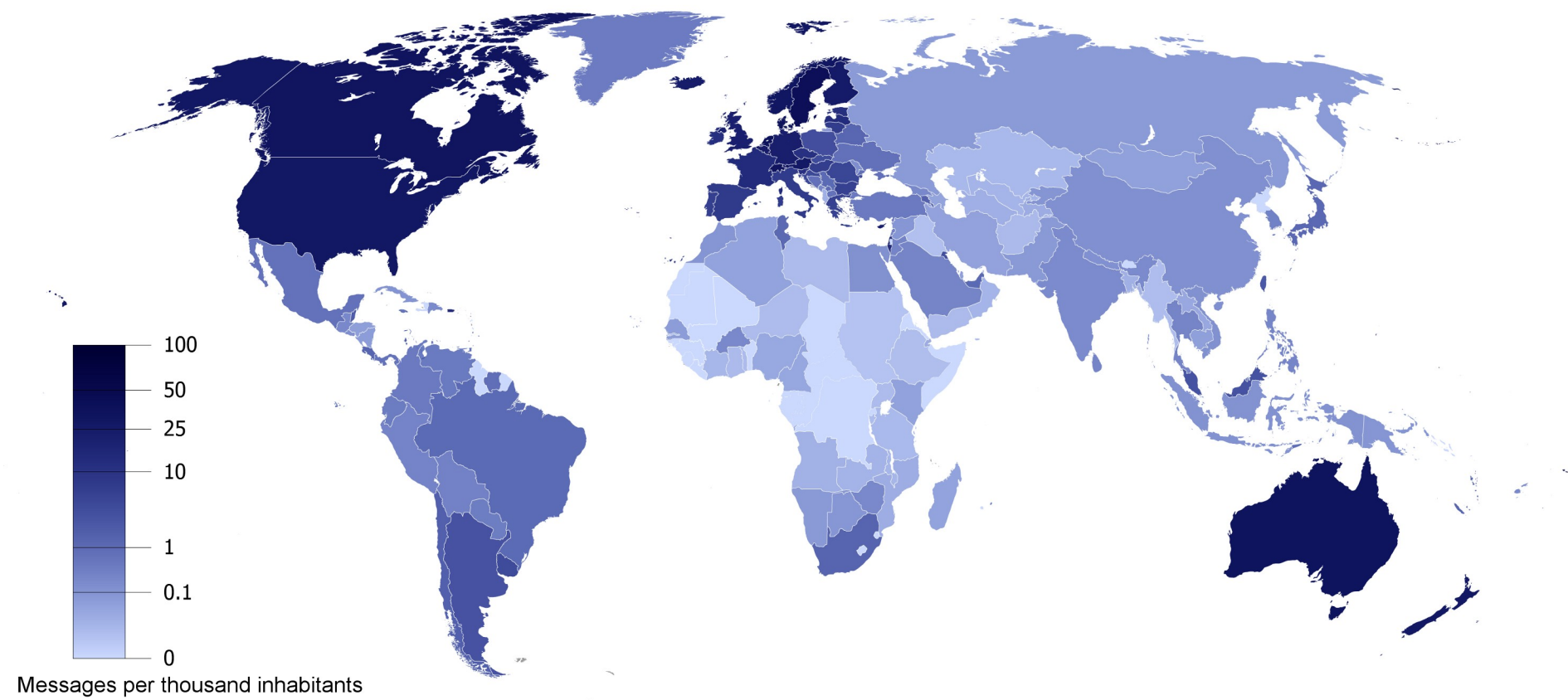
(Source: own calculations)

Figure 4: World Map of *Active* OSS Developers



(Source: own calculations)

Figure 5: World Map of OSS Activities



(Source: own calculations)