Where the Cathedrals and Bazaars Are:

An Index of Open Source Software Activity and Potential

[Shortened Title]

Open Source Software Activity and Potential Index

Douglas S. Noonan
Associate Professor
School of Public Policy
Georgia Institute of Technology

Paul M.A. Baker
Director of Research
Center for Advanced Communications Policy
Georgia Institute of Technology

Art Seavey
New Kind

Nathan W. Moon
Research Scientist
Center for Advanced Communications Policy
Georgia Institute of Technology

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Abstract

This paper presents a framework to measure activity and potential for open source software development and use at a country level. The framework draws on interviews with experts in the open source software industry and numerous existing studies in the literature to identify relevant indicators. Several indices of diverse variable lists and weighting and aggregation methods were developed and tested for robustness. The results provide a first step toward more systematically understanding the current state of open source software internationally.

Keywords: open source software, index construction, technology policy, technology diffusion

1.0 Introduction

Open source software (OSS), also known as Free/Libre/Open Source Software (FLOSS), presents an important case of innovation in software production and distribution. The voluminous literature on OSS includes Steven Weber's (2005) *The Success of Open Source* and Joseph Feller et al.'s (2007) *Perspectives on Free and Open Source Software* in addition to various other works (e.g., Hahn 2002, Weber 2005, Dibona et al. 2005, Bitzer and Schroder 2006, Ghosh 2006). Raymond's (1999) seminal work on OSS portrays a dichotomy between proprietary software and OSS as a cathedral and a bazaar, respectively. The analogy plays on the systematic and revered construction of a cathedral (for proprietary) versus a buzzing bazaar full of decentralized activity (for open source). This paper advances scholarship on the distribution of the bazaar on a global scale by adding empirical detail to the ever-growing literature on both the theory of OSS and its firms and developers. The analysis provides more information about the development, adoption, and diffusion of OSS technology and methods. This initial inquiry into its prevalence should inform the ever-increasing debate and scholarly interest in OSS.

The decision to implement technologies and technological processes is a function of a range of social, economic, and political variables. The involvement of governmental policymakers and regulators, both at the national and sub-national levels, is a critical factor in the deployment and adoption of technologies, both explicitly (in terms of specifications, technical standards, requirements for adoption, etc.) as well as implicitly (the apparent favoring of a technology by government officials as a "pull" factor). This present inquiry maps out the terrain of OSS activity and measures factors that drive OSS potential. Developing a standardized heuristic (in this case, an index) for assessing a country's adoption of OSS can inform future inquiries into both the causes and consequences of where a country falls on a “cathedral-to-bazaar” continuum.

To develop an index of OSS, a conceptual model is introduced that draws a distinction between OSS activity levels and the potential for OSS development. The conceptual model draws on interviews with experts in the OSS industry and numerous studies in the literature to identify relevant indicators. Section 2 describes this literature and expert opinion underpinning the index framework. Section 3 outlines the data collected. Section 4 discusses the construction of indices for robust measurement of OSS activity and potential at a national level. Section 5 reports the results for the OSS indices and sensitivity tests. The final section discusses the broader implications.

2.0 Background

2.1 Literature

While a variety of different approaches exist for the design of an instrument such as an open source index, generally improved validity flows from a systematic examination of supporting literature. In order to devise an index, relevant insights and themes were culled from the existing literature and interviews with software industry experts who specialize in OSS. The results of this literature review are summarized next.

In addition to technological issues, social, cultural, and policy issues also impact OSS diffusion and adoption (Gosain 2003, Lin 2006, Vaisman 2007, Lewis 2008). The social and policy sciences might be said to have arrived relatively late to the “OSS party.” This may be due, in large part, to the paucity of relevant data on the OSS. Ghosh (2007) explains why little empirical evidence exists for explaining why or how the open source model works. Hard data on the monetary value of OSS collaborative development is almost non-existent. This limits economic evaluations, and non-economic activity such as the creation and development of free software is hard to measure in any quantifiable sense. Ghosh contends, therefore, that the lack of objective, “census-type” sources means that many indicators, quantitative and qualitative, may require the use of surveys, which can be costly and unwieldy. Again, with respect to the development of a robust global open source index, the availability of accurate data sources for a wide range of countries is a critical factor in this emerging research area. A number of social scientists have observed the critical data constraint facing this research area (Van Wendel de Joode et al. 2006).

The calls for more social science and policy research into OSS have been numerous. Weber (2000) identifies three key issues for social scientists to investigate: (1) motivation of individuals who develop open source; (2) coordination of activities in the supposed absence of a hierarchical structure, and (3) growing complexity in open source projects and its management. While the purpose of this analysis is to better portray the landscape of OSS activity globally, these issues—in particular the research on motivation (e.g., David and Shapiro 2008, Krishnamurthy 2006, Lerner and Tirole 2005b)—indirectly inform the design of the indices and the selection of indicator variables.

Several themes consistently emerge from the literature. First, technology adoption at the national (country) level is often emphasized. Second, analyses of public-sector OSS adoption usually focus on relevant policy issues. Third, literature on the private sector rarely goes to level of the individual firm. Beyond these issues of adoption, the literature routinely recognizes developer roles in adoption and use. Finally, and almost universally, economic issues pertaining to open source software capture the attention of researchers, but study is still impeded by a lack of quantitative evidence.

Adoption at national (country) level: Scholars have examined the adoption of open source by national governments, particularly through the passage of laws and regulations. By 2001, Peru, Brazil, Argentina, France, and Mexico all had measures pending that would mandate the use of open source software on government computers (Lewis 2008). Other national and sub-national efforts were made in countries such as Germany, Spain, Italy, and Vietnam to establish official alternatives to the use of closed, proprietary software by government (Lewis 2008). When considering open source adoption at the national level, one key issue is governmental, educational, and "third-sectoral" interests in pursuing this option.

Public Sector Adoption and Public Policy Issues: Whereas some governments have begun to *procure* open source software, others, such as Japan, Korea, and China, have actually channeled public funds to large-scale open source development projects (Chae and McHanney 2006). The distinction here, as made by Lee (2006), is that a nation that "considers" OSS signifies its desire to establish a level playing field within the public sector's information technology procurement policies. Such a policy is not necessarily "pro-OSS" because it neither constitutes a government preference for OSS, nor mandates the government to choose it. However, when policy makers decide to "prefer" OSS over proprietary software, the decision is likely to be criticized by proprietary software developers as procurement discrimination. Other issues germane for policy makers include OSS's impact on e-government initiatives. Berry and Moss (2006) discuss circumstances in which the discourse and practice of non-proprietary software contribute to e-government's openness and democratization. OSS can protect and extend transparency and accountability in e-governments, as well as offer opportunities for citizens, non-governmental organizations, public administrators, and private firms to socially shape OSS's direction. Finally, policy issues such as standards settings and open licensing, both of which structure the deployment of open source software, are inherently political processes that also impact technological choices (Simon 2005, Seiferth 1999).

Private Sector Adoption and Use: Within national contexts, the private sector, specifically any firm reliant on information technology, still remains an important stakeholder group when considering the opportunities and barriers to the adoption of open source. Notably, Bonaccorsi and Rossi (2006) call attention to the factors informing private sector decisions about whether to embrace or reject open source. Considerations include economic (price and license constraints), social (conforming to values of OSS community), and technological (exploiting feedback and contributions from developers, promoting standardization, security issues) motivations.

Role of Developers in Adoption and Use Decisions: The motivations of open source developers in the literature have generally been explained in the literature through a taxonomy that considers two components of motivation—intrinsic (e.g., fun, flow, learning, community) and extrinsic (e.g., financial rewards, improving future job prospects, signaling proficiency to others) (Lerner and Tirole 2005a). Krishnamurthy (2006) identifies four important mitigating and moderating factors in the conversation surrounding developer motivation: (1) financial incentives, (2) nature of task, (3) group size, and (4) group structure. Such issues are important because the motivations of open source developers shape socially the adoption of these systems by firms and governmental agencies. Lin (2006) argues that open source development entails a global knowledge network, which consists of: (1) a heterogeneous community of individuals and organizations who do not necessarily have professional backgrounds in computer science, but who have at least developed the competency to understand programming and work within a public domain, and (2) corporations, which results in a hybrid form of software development and distribution.

Economic Issues Pertaining to Open Source Software: Much of the literature on OSS adoption involves the work of economists, many of whom are intrigued by OSS's distinctive mode of technological development, innovation, and distribution, especially its non-proprietary and community-based nature. Lerner and Tirole (2005a) suggest four major issues of interest to scholars studying open source software: (1) technological characteristics conducive to smooth open source development, (2) optimal licensing of open source, (3) the coexistence of open source and proprietary software, and (4) the potential for the open source model to be carried over to other industries. Forge's (2006) analysis of the packaged software industry extends Lerner and Tirole's third point in the context of European economic development, where encouraging OSS may provide a strategic counterbalance against concerns that a few, select proprietary software firms exert excessive market power.

2.2 **Expert Interviews**

A series of in-depth interviews with OSS experts and professionals were conducted in order to inform the design of an index measuring OSS activity. This critical source of insight was gathered from a variety of informant sources via semi-structured interviews conducted jointly by the authors. The interviews were performed in person and, for international informants, via telephone, and each lasted between 30 and 90 minutes. Over a dozen informants were selected from a variety of leadership roles (directors of developer relations, regional markets, legal affairs, policy) within a major international open-source software firm. Building on their cooperation, the interview team then contacted a dozen foreign IT professionals with expertise in the OSS arena, with regional representation including Brazil, Chile, Costa Rica, Mexico, France, Germany, Spain, India, China, the Middle East, Australia and the South Pacific. The interviews discussed such matters as what constitutes OSS activity, on what scales OSS activity can and should be measured, and what facilitates or hinders OSS development and adoption. There was considerable variation in the answers received, even from people within the same organization. Follow-up questions helped to reconcile the variety of responses and start to build a "modal" conception of OSS activity, what composes its critical dimensions, and how to make an index most useful to the professionals and experts in the arena. Quite interestingly, there was strong sentiment among stakeholders for making the index (of open source activity) itself "open source." Keeping the construction of the index transparent, using only public and accessible data sources, and allowing for subsequent modification by the user community were seen as vital elements to any OSS index. The authors agree with this rationale on the grounds that the Index described here will be open to further study and improvement.

2.3 **Index Design: Conceptual Issues**

The design of an open source index poses several interesting challenges. First is the tension between actual, observed OSS activity and latent, potential OSS activity. Both OSS activity and OSS potential have received attention in the scholarly literature, especially whenever questions arise about the future of OSS, the success of OSS relative to proprietary software, or areas where OSS (or institutions or policies) is seen to lag in comparison to other countries or regions. The distinction between active OSS development and adoption versus the potential for such also arose during the expert interviews. Hence, the authors have addressed this dichotomy by developing two different indices, one capturing "activity" (conceptually similar to adoption) and the other capturing "potential" (roughly related to propensity or capacity) in OSS. The open source activity index (A) and the open source potential index (P) are constructed in parallel fashion. The following section describes the basic construction including operational concepts, selection and categorization of variables, and design considerations for modularity and aggregation.

The open source indices are each composed of dimensions, indicators, and variables. Figure 1 depicts this generic structure. The three *dimensions* of both the Activity Index and the Potential Index are composed of government, firm, and community categories. Each dimension is then operationalized by *indicators*, which are generated by a transformation or aggregation of the actual underlying *variables* (data). Each variable in the inventory of data sets is therefore linked to the dimensions via indicators. Of course, an alternative index could employ more, fewer, or different dimensions. These three dimensions[1] emerged consistently from the expert interviews, and most published research on the social and policy aspects of OSS connects closely to at least one of these dimensions. A lengthy candidate variable list is based on the theoretical issues from the literature, consideration of insights and observations from expert informants, and data availability. To develop a global index (rather than just for OECD nations, for instance), with a prerequisite that data be publicly accessible, the data availability criteria proved particularly limiting.

Figure 1: Generic index construction

$$INDEX = f_1(Dimension_1, ..., Dimension_i, ..., Dimension_I)$$

$$Dimension_i = f_2(Indicator_1, ..., Indicator_j, \dots, Indicator_J) \qquad \square i=1,\dots,I$$

$$Indicator_j = f_3(Variable_j) \qquad \square j=1,\dots,J$$

[1] The government dimension included issues of policy and procurement, legal standards, property rights and IP law, civil liberties and democracy and corruption in governance, R&D funding, treaty participation, and other policies. The firms dimension involved commercial enterprises, generally speaking, as well as the broader economy, the ICT infrastructure and workforce, prosperity, and de novo economic and infrastructural growth. The community dimension includes primarily educational attributes like the human capital of the population, computer literacy and training (in CS or in OSS specifically), and the cultural affinity for OSS participation.

A second design consideration relates to both transparency and modularity in the construction of the index. Each candidate variable for inclusion in an index must be identified for a reason; therefore, it is linked to either the Activity or the Potential index. It is also categorized based on one of the three dimensions: government (*G*), firms (*F*), or community (*C*). Each variable is further categorized as being either a direct variable (related to or impacting OSS specifically) or an indirect, contextual variable (e.g., GDP, employment by sector, civil liberties). More direct variables are often preferred because of their closer relationship to OSS, although they are scarcer and limited in the number of countries they cover. Both academic researchers and expert informants recognize these data limitations and regularly employ or recommend indirect variables to describe OSS activity and potential until better data is available. The indices here do likewise in a transparent fashion. Finally, each variable is also categorized as either a ratio or interval measure, for reasons explained below.

A third major design concern relates to the aggregation and "weighting" of variables. In terms of Figure 1, choosing the f_1 and f_2 functions are critical to the index performance. Without some externally validated model to impose structure and weights on the combination of the indicator variables, the design choices by the authors may seem arbitrary. This is a risk facing all such indices, such as the Human Development Index used by the United Nations, the Civil Liberties Index of Freedom House, or the Body Mass Index. In recognition of this important concern, the approach here takes several steps to address possible arbitrariness in construction. First, the index construction is based on an extensive review of the relevant literature and on in-depth interviews with numerous stakeholders. The literature review and interviews were conducted to reveal the relative importance and interrelationships of various themes identified above. Second, several alternative models for the open source index are developed here—each with substantively different designs—allowing for tests of correspondence in index values across alternative models (a type of convergent validity check). If the alternative models yield largely similar results from the index, this lends confidence that the index is not merely an artifact of some arbitrary design choices. The alternative models might best be thought of as experimental approaches to designing a practical open source index. Third, the index construction is fully transparent and replicable by others, inviting everyone to test for sensitivity and make improvements.

Lastly, the index construction is influenced by lessons learned in the extensive literature on environmental sustainability indicators. Like the sustainability indices, of which there are over 15 competing and contested variants, the open source indices require constructing novel indices of complex phenomena where relative weights of indicators might be contested. In particular, care is paid to mitigate the sensitivity of index values to arbitrary weighting and aggregation choices made by the researchers, along the lines of Ebert and Welsch (2004). If an index's rankings shuffle greatly because of different indicator weights, variable transformation (e.g., log or raw income), or other aggregation rules, then the index itself becomes suspect without a credible theory dictating the "appropriate" weight, transformation, or aggregation rule in the OSS index. Ebert and Welsch (2004) show how using a geometric mean (unlike arithmetic means) of ratio variables (rather than interval variables) in the index preserves the rank ordering, regardless of the transformations or weights chosen.[2] This robustness to arbitrary weighting and transformations is a particularly attractive property of the index, and thus geometric means of ratio variables will be preferred as the f_2 function (see Figure 1) whenever possible.

3.0 Index Construction

[2] Ratio variables are those that have natural zero values, such as "population" or "number of Firefox installs." Interval variables, on the other hand, do not have natural zeros, such as "degrees Fahrenheit" or "a dummy variable for whether Linux supports the native language."

3.1 Open Source Index Models

The following section details the actual construction of the models for the Activity and Potential Indices. We also construct a third index to measure a different OSS-related concept, the ratio of activity to potential *(Ratio = A/P)*, where the resulting value could be interpreted as a measure of “realized potential.” Nations with very large *Ratio* values will tend to exhibit more OSS activity relative to what their contextual or environmental factors would predict. (A *Ratio* is available for each pair of *A* and *P* computed.) After some experimentation, several alternative models to construct those indices are proposed here. To indicate the differences in how the index is constructed, each index is denoted with two subscripts. The first subscript indicates the aggregation rules used (technically, which f_1 and f_2 functions are employed). The second subscript indicates which set of variables is used. Each model captures different aspects of the underlying phenomena and consequently has different advantages and limitations. We first discuss data limitations, variable coverage of countries, variable type designations, and aggregation methods.

3.2 **Variables and data sources**

3.21 Data limitations

The OSS indices constructed here employ numerous datasets that are publicly available (with one exception). In a perfect world the indices would draw on a wide variety of datasets populated with systematically, consistently, and comprehensively measured data. Because of the nature of existing international data, however, most variables cover only a limited number of countries and years. In practice, there is a trade-off between the number of countries directly modeled and the range of variables included that span that in turn cover all the countries. Conversely, the larger the number of variables included in the Index the smaller the number of countries for which complete and up-to-date data exist. There are of course several ways in which to deal with this. Future efforts to develop these indices should improve the inclusiveness both cross-sectionally (number of countries) and longitudinally (over time) in the dataset. This is particularly important for the variables directly related to OSS.

3.22 **Variable coverage (*L*, *S*)**

To show this trade-off, this paper reports indices for a “long” and a “short” list of countries. Variables are classified according to whether they cover a “short” (roughly N < 100) or a “long” (N > 120) list of countries. “Short” (*S*) variables tend to be of higher quality or more directly related to important indicators, whereas “long” (*L*) variables are more general and only indirectly relate. The index construction recognizes this balance and separately creates “short” and “long” versions of each index—where the latter sacrifices some variable quality in order to obtain greater coverage of countries. In one sense, the comparison is between a higher-quality index measuring OSS activity/potential among relatively “elite” countries and a lower-quality index measuring OSS activity/potential among a more inclusive group.

3.23 **Variable types (*B*, *R*)**

Following Figure 1, indices *A* and *P* are computed here using the same general structure: combining multiple dimensions, several indicators for each dimensions, and variables measuring those indicators. Table 1 first shows the various indicators for each dimension. Table 1 also lists the names of the variables chosen for each indicator in the *A* and *P* indices. (Note that the top variable of each pair in a cell is the “long” variable). Variables are further classified according to their nature as interval- or ratio-scale measures and whether they are the best available variable for a particular indicator. The best available proxy for each indicator is listed under that column in Table 1. More direct measures are preferred to indirect measures of the indicator, when available. The best long or short variable may differ for some indicators. Similarly, the best available ratio-scale proxy variable is listed under that column in Table 1. Ratio-scale variables possess useful properties for preserving rank-ordering, as discussed. Logically, the best variable differs from the ratio-scale variable only when the best variable is an interval-scale measure. In general, each set of indicators is drawn from variables that are either best (*B*) or ratio-scale (*R*) and either short (*S*) or long (*L*) depending on how many missing values it has. Thus, there are several variations of each index *A* or *P*, denoted with subscripts either *BL*, *BS*, *RL*, or *RS* to indicate the set of variables used in its construction. Many of the variables are shared across multiple models in this application. Definitions and sources for the variables listed in Table 1[3] can be found in Table A1 in the Appendix.

Table 1: Indicators and Variables Selected

Index	**Dimension**	**Indicator**	**Best**	**Ratio**
Activity	*G*	procurement	OSSpolNatman GovExppGDP	GovExppGDP GovExppGDP
		policy	OSSpolNatRD OSSfunding	OSSpolNatRD OSSfunding
		use		
	F	RHCEs & other developers	RHCEpc RHCEpc	RHCEpc RHCEpc
		firms' installs/users	LinuxUserspc LinuxUserspc	LinuxUserspc LinuxUserspc
		firms developing/ supporting OSS		
	C	household installs/users, Wiki participants	GoogleApp GoogleApp	GoogleApp GoogleApp
		OSS courses, adoption by educators	SchoolNet	. SchoolNet
		discussion in media	rOSSnews rOSSnews	rOSSnews rOSSnews

[3] Notice the grey-shaded cells, where only 6 out of 46 cells do not have a suitable and available variable at this time. Filling in these blanks is a task for future research. For now, these gaps are minor and need not preclude the construction and testing of these preliminary indices. Only two out of the 23 total indicators have no variables available, and neither affect the potential index.

		language supported	LinuxLang LinuxLang	
Potential	G	software policy	nPiracy OOXML	nPiracy nPiracy
		corruption and liberties	nCivLib nCivLib	Turnout Turnout
		e-government	eGov eGov	eGov eGov
		IP law	nTRIPS nIPRI	
	F	IT industry size/competition	ICTtop250pGDP ICTtop250pGDP	ICTtop250pGDP ICTtop250pGDP
		IT growth	newCellGro TelcomInvestpc	newCellGro TelcomInvestpc
		R&D	SciArticlespc RnDemploypc	SciArticlespc RnDemploypc
		internet access	nNetPrice nNetPrice	nNetPrice nNetPrice
		de novo growth	inewGrowth inewGrowth	inewGrowth inewGrowth
	C	culture	TVpc TVpc	TVpc TVpc
		education	College GradEngpgrad	College GradEngpgrad
		CS majors	PCspc PCspc	PCspc PCspc
		internet users	InternetUserspc InternetUserspc	InternetUserspc InternetUserspc

3.24 **Additional variables**

Although Table 1 lists the primary variables (those used in all the indices), they are drawn from a much larger pool of candidate variables—each of which is classified similarly (i.e., as long, short, best, ratio, interval) and associated with an indicator. Additional variables, beyond those in Table 1, appear in Table A1. Indices constructed with a weighted average make use of additional variables indirectly measuring OSS aspects of a country, as described below. For instance, the "Firefox users" variable relates directly and "PCs per capita" variable relates indirectly to the *household installs* indicator (an activity indicator in the Community dimension).

3.25 **Missing values**

Missing values are prevalent in the datasets used here and, unfortunately, require difficult choices and compromises in order to produce an index. Rather than collect primary data, this analysis occasionally imputes missing data. Because many variables were missing values for most of the countries, imputation is resorted to only in the rare instances when it was both very useful (e.g., imputing a single value meant that the country would not be dropped from the index) and when close proxies were available. Generally, rather than mask this tradeoff through statistical imputation techniques, the trade-off between data coverage (i.e., more countries in the index) and data quality (i.e., more and better variables in the index) is handled transparently in this analysis by reporting both *L* and *S* indices.

A major concern in imputation is that the likelihood of a missing value for a particular country might be correlated with that (missing) value. Using other countries' values to impute the missing value might bias the estimated value if there is something special about the country with the missing observation that makes the countries with complete data non-representative. This is especially likely to pose a problem for international data where, for instance, a variable might be available only for OECD countries and, obviously, countries belonging to the OECD differ from non-OECD countries in numerous ways. Imputation is employed here only in instances when a particular county has a missing value in the current (i.e., most recent) year for which that variable is collected and there are earlier observations for that variable in that country. In these cases, a linear imputation is employed in order to estimate what the “current” value for that country would be (using only its prior years' values).

3.3 **Aggregations**

3.21 Transformations (f_3) and rescaling

Most variables are transformed via the f_3 function in order to create the indicators. This initial transformation is critical because the index combines heterogeneous variables with widely varying units of measurement. Combining count variables (e.g., number of applications to Google's "Summer of Code" program) with indicator variables (e.g., country has an OSS procurement policy) and with other types of variables requires transforming or rescaling the original input variables into more commensurable indicators. Similarly, scale effects arising from the variation in sheer size of countries can demand that some variables (e.g., number of Red Hat Certified Engineers) be measured proportional to country size. Without that rescaling, these variables would essentially proxy for country size rather than intensity of OSS activity or potential. Thus, all variables are normalized (i.e., transformed to a Z-score) before entering the index. Any other rescaling is described in the variable definition in Table A1.

3.22 **Aggregating indicators (f_2) to obtain dimensions**

After rescaling and normalization (and the few imputations) are completed, the next step is to settle on the f_2 functions that aggregate the multiple indicators into single dimension values. These functions could include an arithmetic mean (a), a geometric mean (g), a maximum value (x), and a minimum value (i). Aggregating across different indicators within a particular dimension is also sensitive to instances where a country is missing values for one or more of those indicators. For the minimum, maximum, and arithmetic mean aggregations, missing values for the constituent indicators are ignored and the operation is applied to the remaining indicators (unless fewer than two indicators values existed, in which case the dimension value is also missing).

A fourth type of aggregation function is also considered: the geometric mean. The geometric mean aggregation bears some distinction as being the most robust, in theory, to arbitrary scaling effects for ratio-scale variables (see Ebert and Welsch, 2004, and others). The advantage of geometric mean indices arises when ratio-scale variables are used, thus a *g* index will always imply *R (ratio)* variables. A trade-off arises here because several components of the indices such as measures of "liberty" or "language" are typically only found in interval-scale. For aggregation by geometric mean, the dimension value is assigned a "missing" value if all or all but one constituent indicators have missing values. This geometric aggregation rule limits its sensitivity to holes in the data (although, as a tradeoff, fewer countries can be included in this index).

3.23 **Aggregating dimensions (f_1) to obtain indices**

The last step in initially constructing the indices involves deciding on the aggregation function f_1 to compile the three dimensions into a single, final index value. Common choices for aggregating the dimensions include arithmetic means (*a*), minimum values (*i*), and maximum values (*x*). Because the dimensions themselves are aggregates of indicators, this 'aggregation of aggregations' permits a large number of combinations of the f_1 and f_2 functions. Five basic combinations are reported here: *aa* (mean-mean, or arithmetic mean of arithmetic means), *ag* (mean-geometric mean, or arithmetic mean of geometric means), *ia* (mini-mean, or minimum of arithmetic means), and *xi* (maxi-min, or maximum of minimums).[4] The first two are our preferred constructions, because they are easiest to interpret (*aa*) and have nice robustness properties (*ag*). The third is the "weakest" dimension, where dimensions are themselves averages. The fourth is the "best" dimension, where dimensions are measured by their weakest

[4] Just as the indicator aggregations (f_2) were sensitive to missing values, so are the index aggregations (f_1) of dimensions. The indicator aggregation rules described here allow the dimension value to be computed even if one or more indicator values are missing. The index aggregation rules used here, however, do not. If a country is missing a value for one or more of its dimensions, an index value is not computed for that country.

contributor. Of course, other aggregations are possible as well (e.g., *ii* or “mini-min”, *xi* or “maxi-min”). The many different combinations of aggregation rules (f_1 and f_2 functions) possible allow us to conduct sensitivity tests for the index.[5] These sensitivity checks are discussed in Section 5.

The preferred constructions (*aa*, *ag*), reported in Section 4, highlight three attributes of the OSS index: robustness, ease of interpretation, and comprehensiveness. The robust index (*ag*) is an arithmetic mean of geometric means. Using the *S* (short country span) variables further enhances its robustness, while sacrificing some sample coverage. The more easily interpreted index (*aa*) is an arithmetic mean of arithmetic means, which is also the most comprehensive if the *L (long country span)* variable set is used. The index construction described here applies to both the activity (*A*) and the potential (*P*) indices.

3.24 **Weighted average indices**

The *aa* and *ag* aggregations give equal weights to the three dimensions (government, business, and community). Of course, the weight can be readily adjusted to suit other index users’ preferences or purposes. Although an equal weighting followed from our extensive review of the literature in conjunction with input from various industry sources, a weighted average is worth pursuing to check for sensitivity. Unfortunately, any weighting scheme risks the appearance of arbitrariness. To mitigate this, we introduce an endogenous weighting approach where the weights are based on existing relations in the data. In this approach, all proposed variables are classified as either *directly* related to OSS (e.g., Firefox downloads, government OSS policies, number of Red Hat Certified Engineers) or *indirect*, contextual variables (e.g.,

[5]For each of three dimensions (government, firms, community), we consider five different aggregation rules for f_2, two different sets of indicators depending on data coverage (*L* or *S*), and two different sets of indicators based on type (*B* or *R*). This generates, essentially, some 60 different possible sub-indices for *A* and 60 more for *P*, which are subjected to a sensitivity analysis. The results reported here are among the least sensitive to these choices and the extent of this sensitivity is reported in discussion section.

GDP, employment by sector, civil liberty index). For the *A* index, dimension (*G*, *F*, *C*) values are then computed using the best direct measures of *A* available and an arithmetic mean (or minimum) aggregation f_2. Next, each dimension value is regressed on the many indirect variables associated with *A*.[6] The fitted values from each dimension's regression are then aggregated as a weighted average (f_1), where the weights are the R^2 values from the regressions. Thus, the index value is a weighted average score across the different dimensions. The weights depend on how well the variables directly measuring OSS are explained by the indirect measures. The country's dimension values depend on its contextual values.

Using fitted values to compose the dimension values has the dual advantages of enabling greater coverage (a country that has a missing value for the direct variable can still have a predicted value) and of purging the dimension values of larger residuals or anomalous values in direct measures. Allowing the weights to derive from the auxiliary regressions replaces an arbitrary weighting imposed by the researchers with one that directly reflects to the extent to which variation in the direct OSS measure is explained by the data at hand. Dimensions that are better explained or predicted are thus given greater weight. On the other hand, this model reduces the ability of the analyst to apply expert knowledge or to experiment with their own weighting preferences. This procedure can be performed with direct variables that have more (*S*) or fewer (*L*) missing observations. All of this is done separately for activity and for potential variables and is denoted with *wa* for weighted average. There are 26 indicators[7] used to construct

[6] To construct the weighted averages, direct measures in each of the three dimensions are regressed on the set of indirect variables – making for three equations simultaneously estimated using least squares. A seemingly unrelated regression (SUR) framework is employed thereby allowing the error terms in each equation to be correlated, which seems plausible a priori because a country's unobservable OSS aspects may be correlated across dimensions. The SUR approach proves unnecessary with this data, as the independence of the equations cannot be rejected and separate regressions can suffice.

[7] These include: rOSShits, GDPpcPPP, PCpc, XPpGDPm, iServerspc, InternetHostspc, OSSpolNat, OSSpolMun, OSSpolNatRD, OSSpolMunRD, dOSSpolNat, dOSSpolMun, dOSSpolNatRD, dOSSpolMunRD, OSSpolNatadv, OSSpolNatman, OSSpolNatpre, OSSpolMunadv, OSSpolMunman, OSSpolMunpre, dOSSpolNatadv,

A_{wa} and 27 indicators[8] for P_{wa}. Table A1 in the Appendix also contains their definitions.

Finally, the *Ratio* index is derived directly from a pair of *A* and *P* indices' ranks. As such, it reflects the variations in constructions of *A* and *P*. It must be emphasized, however, that the *Ratio* index is a distinct index that measures something different than either activity or potential. Scaling a country's OSS activity by its OSS potential allows users to readily see which countries are "overachieving" and which are "underachieving" relative to their potential. In gross terms, this suggests where OSS growth potential is greatest. Decomposing the index, perhaps by re-weighting the dimensions constituting *A* and *P*, can suggest explanations for why some countries are over- or under-performing in OSS.

4.0 **Results**

4.1 Descriptive statistics for the indices

With so many possible indices to construct given the available data, only some of them can be described here for the sake of brevity. Table 2 reports descriptive statistics for four versions of the activity index ($A_{aa,BL}$, $A_{aa,BS}$, $A_{ag,RS}$, and A_{wa}), four corresponding potential indices ($P_{aa,BL}$, $P_{aa,BS}$, $P_{ag,RS}$, and P_{wa}), and two ratios ($Ratio_{ag,RS}$, $Ratio_{aa,BL}$). While Table 2 offers little in the way of intuition due to the varying scales across the indices, a few things should be evident at first glance. First and foremost, the number of countries (N) for which the index is available varies greatly across indices, as expected. Second, the variance in the index value differs widely across indices, suggesting that some index constructions involve more tightly clustered values than others. Given that the index values themselves have little cardinal meaning, we confine our

dOSSpolNatman, dOSSpolNatpre, dOSSpolMunadv, dOSSpolMunman, and dOSSpolMunpre. Because the Index C construction uses a linear fit of these variables and individual coefficients are not of particular interest, linear rescaling is inconsequential and so the variables enter the regressions in their raw form.

[8] These include: Age2529pc, Age2024pc, TVpc, urbanpc, Age1524pc, Literacy, HSenroll, HSvoc, newspc, InternetUserspc, Phonespc, Radiopc, Cellspc, PhoneUSA, PhoneLoc, Phonelinespc, Phonelinespworker, PhoneWaittime, Phonepc, nNetPrice, GDPpc, TradepGDP, ICTpExport, SciArticlespc, POiGov, POinternet, and nWTO. Because the Index C construction uses a linear fit of these variables and individual coefficients are not of particular interest, linear rescaling is inconsequential and so the variables enter the regressions in their raw form.

interest to ordinal or rank values. Finally, not visible in Table 2 is that the weights across dimensions in A_{wa} and P_{wa} are not generally wildly different.[9]

Table 2: Descriptive Statistics for Select Indices

Variable	Obs (N)	Mean	Std. Dev.	Min	Max
$A_{ag,RS}$	47	0.69	0.66	0.00	2.02
$P_{ag,RS}$	105	7.29	6.07	0.98	44.23
$A_{aa,BS}$	47	0.36	0.52	-0.87	1.60
$P_{aa,BS}$	60	0.26	0.44	-0.73	1.27
$A_{aa,BL}$	132	0.11	0.58	-0.59	1.78
$P_{aa,BL}$	138	-0.01	0.60	-1.05	1.52
A_{wa}	121	0.00	0.51	-0.68	1.66
P_{wa}	74	0.02	0.56	-0.88	1.46
$Ratio_{agRS}$	42	0.09	0.10	0.00	0.43
$Ratio_{aa,BL}$	107	1.59	9.82	-9.78	81.30

Table 3 shows select pairwise rank correlations among the indices reported in Table 2. Each cell reports the Spearman correlation (and the number of observations used to compute it) between two corresponding indices. In other words, only correlations between activity indices or between potential indices are shown. The correlations reported in Table 3 are all statistically significant, positive, and in many cases generally quite large. The alternative index designs do appear to be measuring roughly the same thing. While some concern about the robustness of the activity measures is warranted due to the lower pairwise correlations with $A_{ag,RS}$, this result arises largely because of the particular ratio-scale variables used in the $A_{ag,RS}$ index.[10] Aside from the weaker relationship between the *R* and *B* variable sets for the activity index, the correlations range between 0.70 and 0.95 and are all significant at the 1% level. For the arithmetic mean

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[9] For example, the weights for the *G*, *F*, and *C* dimensions in A_{wa} are 0.979, 0.896, and 0.818, respectively. The corresponding weights for P_{wa} are 0.833, 0.839, and 0.951.

[10] As shown in Table 5 in section 5, the rank correlations between the A_{ag} and other versions of *A* are significant and greater than 0.5 when the other versions use the ratio-scale variables or when computing $A_{ag,RL}$ with the "long" set of ratio-scale variables.

indices, the long and short versions are correlated at 0.73 and 0.93 for the activity and the potential indices, respectively. This suggests that the cost, in terms of variable quality, for switching to variables that have a greater coverage of countries is relatively small, especially for the potential index. The rank orderings are also similar between the arithmetic mean and the weighted average versions. Whether it is 40 or 100 countries, the simple arithmetic mean generates a rank ordering that is highly correlated with the weighted-average approach. Table 3 suggests that the cost, in terms of less intuition and perhaps less valid proxy variables, for using the geometric means of ratio-scale variables to enhance robustness may be more substantial, however. Correlations in the first two columns of Table 3 are weaker, as would be expected given its nonlinearity and the restricted set of indicators.

Table 3: Rank-correlations, selected indices

	geometric mean ($X_{ag,RS}$)		**weighted mean (X_{wa})**		**arithmetic mean ($X_{aa,BL}$)**	
X=	*A*	*P*	*A*	*P*	*A*	*P*
$X_{aa,BS}$	0.4245* 47	0.6966* 56	0.7056* 46	0.9362* 40	0.7314* 47	0.9312* 60
$X_{aa,BL}$	0.4926* 47	0.7676* 103	0.8958* 103	0.9524* 71		
X_{wa}	0.4606* 46	0.7716* 63				

Table 4 shows the countries with the 20 highest values in several representative indices. It should be emphasized that the pool of countries included differs across indices, which complicates direct comparisons between the columns in Table 4. The first two columns derive from the geometric mean versions $A_{ag,RS}$ and $P_{ag,RS}$ reported in Table 2. Thus, these rankings are based on the index design preferred for its robustness. The next two columns do likewise for the arithmetic mean versions $A_{aa,BL}$, and $P_{aa,BL}$. These rankings are based on the index design preferred for its ease of interpretation and comprehensiveness.

Table 4: Top 20 Countries in $X_{ag,RS}$, $X_{aa,BL}$

(rank) country			
$A_{ag,RS}$	$A_{aa,BL}$	$P_{ag,RS}$	$P_{aa,BL}$
1) Sweden	Spain	Iceland	Sweden
2) Ireland	France	Vanuatu	USA
3) France	Belgium	Latvia	Norway
4) United Kingdom	Iceland	Croatia	Denmark
5) Finland	Brazil	Czech	United Kingdom
6) Pakistan	Norway	South Korea	Canada
7) South Africa	United Kingdom	Lithuania	Netherlands
8) Paraguay	Qatar	Poland	Finland
9) Bulgaria	Denmark	Singapore	Switzerland
10) Vietnam	Finland	Slovenia	Australia
11) Israel	Taiwan	Panama	New Zealand
12) China	Peru	Cyprus	South Korea
13) Norway	Australia	Germany	Japan
14) Spain	Sweden	Hungary	Israel
15) Philippines	China	Estonia	Austria
16) Italy	Italy	Greece	France
17) Brazil	Netherlands	Ukraine	Germany
18) Venezuela	USA	Sweden	Belgium
19) Netherlands	Japan	USA	Iceland
20) Denmark	Estonia	Japan	Estonia

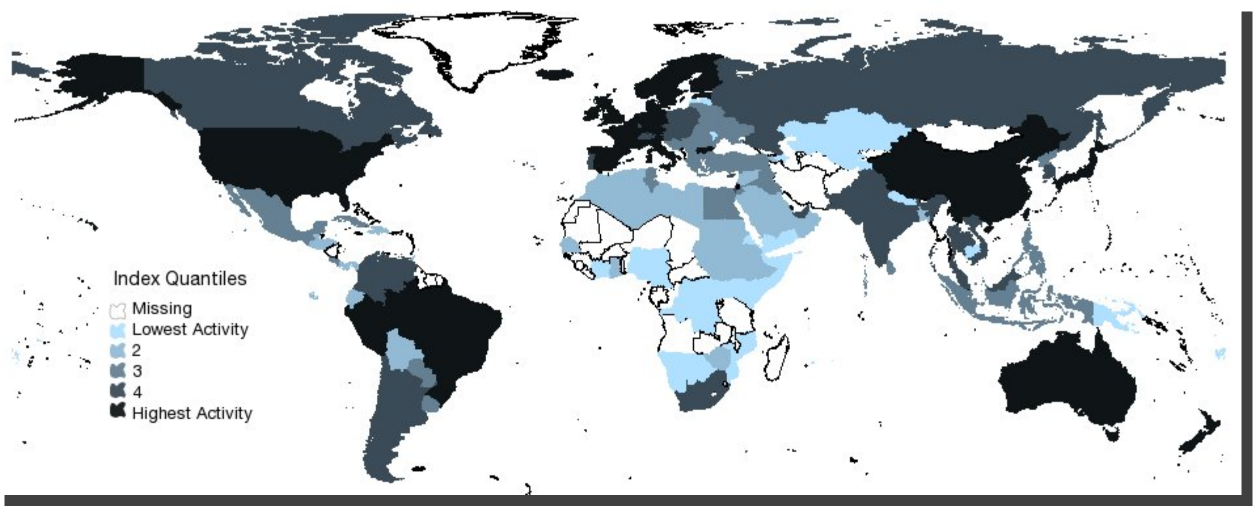
4.2 Maps

Figure 2 depicts maps of three different index values across the panels. Panel A and Panel B show the most comprehensive indices $A_{aa,BL}$ and $P_{aa,BL}$, respectively, while Panel C shows $Ratio_{wa,BL}$ (ratio of Activity to Potential). Higher index values are shaded darker, while countries with missing data are not colored in the world map. The maps indicate some broad patterns. Africa and the Middle East (and, to a lesser extent, eastern Europe, central America, and southeast Asia) lag behind in the OSS activity. South America shows a mix of activity, while

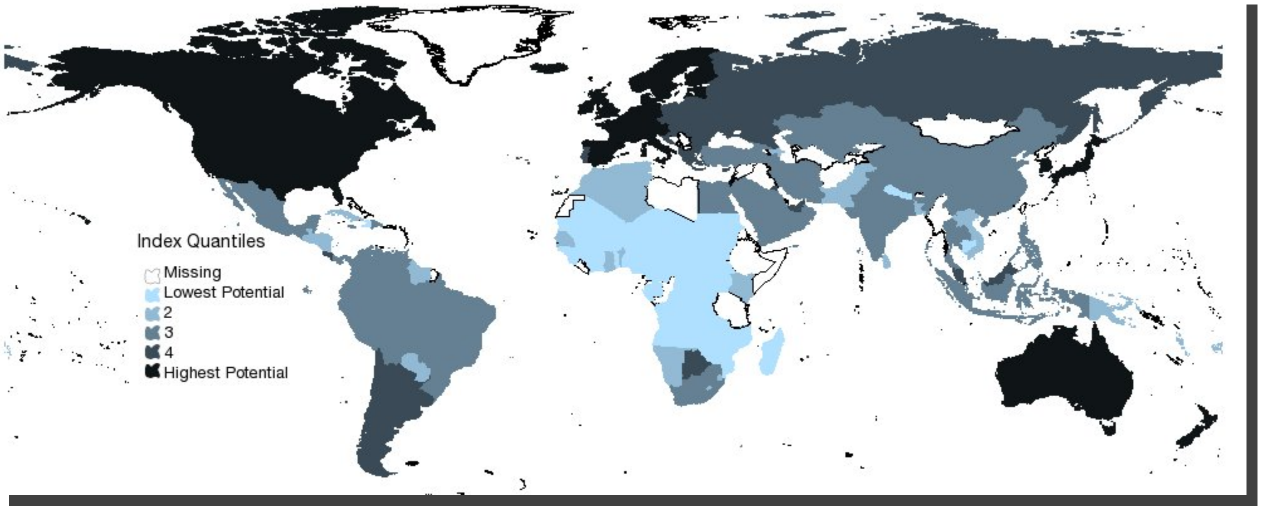
South Africa stands out as the leading African nation. Solid performances are visible in high-profile OSS countries such as Brazil and Peru in South America and China, Japan, and Taiwan in Asia. The potential index maps shows a different pattern, one more broadly reflective of economic development and prosperity indicators. The ratio index map can be viewed, then, as depicting the extent of OSS activity relative to their background level of development or potential. Here, the OSS success of some high-profile countries (e.g., Brazil, Spain) stands out along with the success of some less noticed countries (e.g., Uzbekistan, Bulgaria). The regional patterns evident in Panel A are less distinct in Panel C, representing how the ratio index captures more than just regional patterns in economic development. Each continent appears to have considerable variation: some countries with high ratios (e.g., U.S., Spain, Oman, Ecuador, Egypt) and some with low ratios (e.g., Mexico, Switzerland, Peru).

Figure 2: Maps of select index quantiles (5)

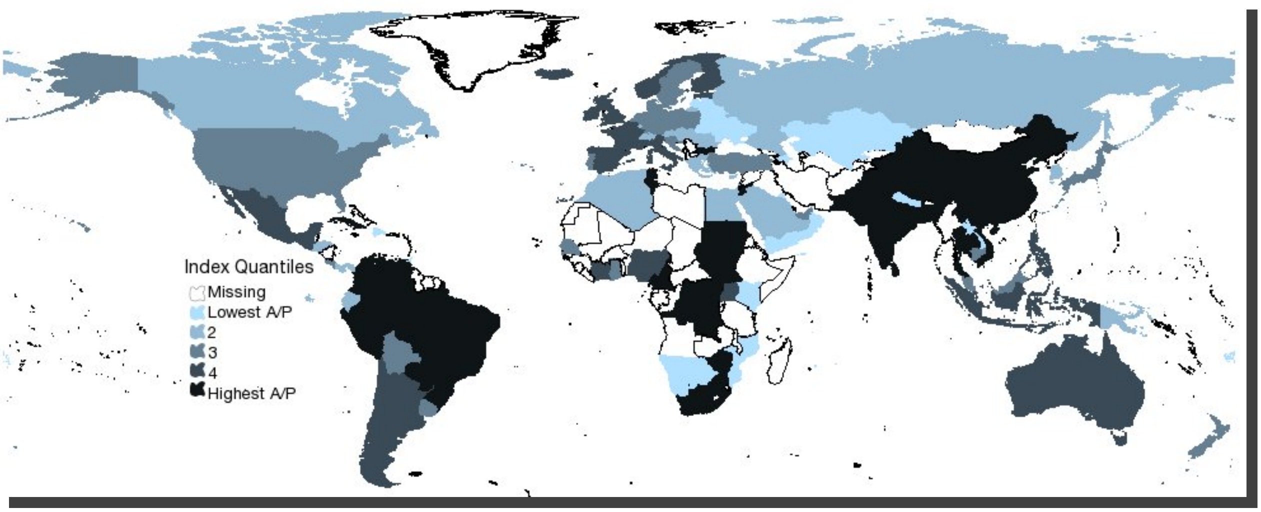
Activity Index Map ($A_{aa,BL}$)



Potential Index Map ($P_{aa,BL}$)



Ratio A/P ($Ratio_{wa,BL}$) Index Map



5.0 **Sensitivity Analysis**

With many candidate indices (and sub-indices), tests for robustness to different aggregation rules, sample sizes, and measure types are critical. The primary concern here is with correlations in rank-orderings (rather than raw values) derived from each index. Ideally, the OSS indices that measured similar things would not vary dramatically across different aggregation rules or types of measures. To the extent that the index is sensitive to these design choices, the usefulness of the index should be questioned.

Table 5 summarizes some of the observed Spearman rank-order correlations between alternative indices. Some variation is to be expected given that the different indices aim to measure different things (e.g., activity vs. potential vs. their ratio) and they employ different variables. Overall, a good deal of stability is found across aggregation rules. For the activity indices, all rank correlations are positive and nearly all are significant at the 5% level (usually at the 0.1% level). Rank correlations across different aggregation rules (while using the same indicators) are quite strong. Across 101 countries, the *A* ranks are significantly correlated between the arithmetic mean aggregation and the geometric mean (0.75), the maxi-min (0.69), and the mini-mean (0.64). Rank orderings do vary if the *A* depends on averages of indicators or on the "weakest link" of those indicators, but the rankings are still closely correlated. For similar index constructions, the correlations are even stronger. Indices with the same aggregation rules but different indicators (e.g., $A_{aa,BL}$ and $A_{aa,BS}$), are highly correlated; significant Spearman correlation coefficients exceed 0.5 in all but one case. For example, the rank correlation between long and short indices is 0.73 when using the best indicators and a simple arithmetic mean, and it is 0.90 when using ratio-scale variables and a geometric mean. Perhaps the strongest evidence that the *A* index is robust to aggregation rules (and even to alternate indicator variables) can be found in the high rank-correlation coefficient (0.82) between the preferred arithmetic mean and geometric mean indices for the "long" indicators ($A_{aa,BL}$, and $A_{ag,RL}$). Somewhat troubling is the weaker rank correlation for the corresponding "short" indicators. The short indices, which use better indicators but at the cost of a reduced sample, have weaker correlations across aggregation rules ($A_{aa,RS}$ and $A_{ag,RS}$ are correlated at 0.40). Similar results, often even stronger, hold even if the correlations reported in Table 5 are computed using casewise deletion (so that the same set of countries is used throughout). Moreover, as the lower half of Table 5 indicates, these general observations about the strength of correlations hold when looking at the potential indices (P).[11] Finally, Table 5 shows that the P indices are closely rank-correlated with P_{wa}. The indices are largely robust to alternative weights for averaging.

Table 5: Select index rank correlations

Activity									
	$A_{aa,BL}$	$A_{aa,BS}$	$A_{aa,RL}$	$A_{aa,RS}$	$A_{ag,RL}$	$A_{ag,RS}$	$A_{xi,BL}$	$A_{ia,BL}$	A_{wa}
$A_{aa,BL}$	1								
	132								
$A_{aa,BS}$	0.7314*	1							
	47	47							
$A_{aa,RL}$	0.7238*	0.7544*	1						
	101	47	101						
$A_{aa,RS}$	0.5611*	0.8414*	0.8897*	1					
	29	29	29	29					
$A_{ag,RL}$	0.8189*	0.4272*	0.6380*	0.3862*	1				
	101	47	101	29	101				
$A_{ag,RS}$	0.4926*	0.4245*	0.4185*	0.3961*	0.8957*	1			
	47	47	47	29	47	47			
$A_{xi,BL}$	0.8757*	0.7100*	0.6977*	0.3488	0.6991*	0.1962	1		
	132	47	101	29	101	47	132		
$A_{xi,BS}$	0.6074*	0.8111*	0.5649*	0.6471*	0.2364	0.2008	0.8106*		
	47	47	47	29	47	47	47		
$A_{xi,RL}$	0.8366*	0.4301*	0.6965*	0.3433	0.8833*	0.8447*	0.7429*		
	101	47	101	29	101	47	101		
$A_{xi,RS}$	0.5907*	0.5668*	0.4712*	0.3839*	0.7740*	0.9483*	0.3205		
	29	29	29	29	29	29	29		
$A_{ia,BL}$	0.8411*	0.5932*	0.6455*	0.6312*	0.6674*	0.4017*	0.7103*	1	
	132	47	101	29	101	47	132	132	

[11] In many cases, the correlations are even stronger (e.g., $P_{aa,BL}$ has a greater rank-correlation with $P_{aa,BS}$ and $P_{ag,RL}$) but remain generally consistent with the activity variables. One exception is with the $P_{ia,RL}$ index, which is generally negatively correlated with other index measures. This surprising result largely follows from a negative correlation between the F dimension in the ratio-scale and the C dimension with the best variables *for this subset of countries*. This peculiar result poses only a minor concern because the odd-behaving ratio-scale version of P with a mini-mean aggregation is useful primarily for comparison to $P_{ag,RL}$, especially given that the superior $P_{ia,BL}$ index is present.

$A_{ia,BS}$	0.4556*	0.6619*	0.6244*	0.5966*	0.4372*	0.4307*	0.5663*	0.7553*	
	47	47	47	29	47	47	47	47	
$A_{ia,RL}$	0.7381*	0.7922*	0.6032*	0.4655*	0.5742*	0.0916	0.7667*	0.7595*	
	101	47	101	29	101	47	101	101	
$A_{ia,RS}$	0.4409*	0.7138*	0.3222	0.4655*	0.0128	0.1621	0.6112*	0.5264*	
	29	29	29	29	29	29	29	29	
A_{wa}	0.8958*	0.7056*	0.6459*	0.5448*	0.7843*	0.4606*	0.8058*	0.7319*	1
	103	46	89	29	89	46	103	103	121
A_{wi}	0.8578*	0.8310*	0.6856*	0.6970*	0.7698*	0.4674*	0.8013*	0.7215*	0.9605*
	103	46	89	29	89	46	103	103	121
Potential									
	$P_{aa,BL}$	$P_{aa,BS}$	$P_{aa,RL}$	$P_{aa,RS}$	$P_{ag,RL}$	$P_{ag,RS}$	$P_{xi,BL}$	$P_{ia,BL}$	P_{wa}
$P_{aa,BL}$	1								
	138								
$P_{aa,BS}$	0.9312*	1							
	60	60							
$P_{aa,RL}$	0.7751*	0.8024*	1						
	77	51	77						
$P_{aa,RS}$	0.9316*	0.8857*	0.7820*	1					
	56	51	56	56					
$P_{ag,RL}$	0.9063*	0.8984*	0.7099*	0.8949*	1				
	111	56	77	56	128				
$P_{ag,RS}$	0.7676*	0.6966*	0.6391*	0.7047*	0.7549*	1			
	103	56	76	56	105	105			
$P_{xi,BL}$	0.8963*	0.8785*	0.8070*	0.9183*	0.8030*	0.7404*	1		
	138	60	77	56	111	103	140		
$P_{xi,BS}$	0.3913*	0.4903*	0.2588	0.2867	0.3580*	0.3805*	0.3669*		
	37	35	32	32	34	34	37		
$P_{xi,RL}$	0.5429*	0.7602*	0.6048*	0.8658*	0.5918*	0.3357*	0.4947*		
	108	56	70	52	92	88	108		
$P_{xi,RS}$	0.1884	0.2958	0.1151	0.0894	0.1664	0.3971*	0.2347		
	37	35	32	32	34	34	37		
$P_{ia,BL}$	0.9490*	0.9440*	0.7307*	0.9012*	0.8923*	0.7459*	0.8676*	1	
	138	60	77	56	111	103	138	138	
$P_{ia,BS}$	0.8442*	0.9042*	0.6943*	0.8144*	0.7682*	0.6460*	0.7928*	0.8575*	
	60	60	51	51	56	56	60	60	
$P_{ia,RL}$	-0.4131*	-0.4488*	-0.1247	-0.3436*	-0.4384*	-0.0764	-0.3619*	-0.3731*	
	77	51	77	56	77	76	77	77	
$P_{ia,RS}$	0.6742*	0.5959*	0.6123*	0.6798*	0.7290*	0.4700*	0.6703*	0.6632*	
	56	51	56	56	56	56	56	56	
P_{wa}	0.9524*	0.9362*	0.7106*	0.9127*	0.9256*	0.7716*	0.8352*	0.9264*	1
	71	40	49	38	63	63	71	71	74
P_{wi}	0.7607*	0.8906*	0.7327*	0.8602*	0.7355*	0.6733*	0.8016*	0.7801*	0.7348*
	71	40	49	38	63	63	71	71	74

* indicates significant at the 5% level. Top number indicates Spearman rank correlation coefficient; bottom number indicates number of observations. Shaded cells indicate correlations between indices with similar f_1 and f_2 aggregations. Dark-outlined cells indicate correlations between indices with similar variable sets.

Because the open source index is composed of three different sub-indices or dimensions, the robustness of the dimensions to alternative approaches also merits some scrutiny. As in Table 5, Table 6 shows the rank correlations between various constructions of the government (*G*), firms (*F*), and community (*C*) dimensions of the OSS indices. The dimension values are highly rank-correlated with one another even when produced with different aggregations or variable sets. This is especially true for the dimensions in the activity index, where the pairwise rank correlations between dimensions that use different aggregation rules or different variable lists are typically well over 0.7 and often over 0.95. The *G* and *F* dimensions for the potential index exhibit somewhat less consistency, where the $P_{\cdot i,BS}$ and $P_{\cdot g,RS}$ dimensions are weakly or uncorrelated with other aggregations using similar indicators. Although this presents some reason for caution, it bears emphasis that Table 6 shows rank correlations for 48 different dimension measures, and a few weak correlations are to be expected.

Table 6: Select dimension rank correlations

Activity	Government							
	$A_{\cdot a,BL}$	$A_{\cdot i,BL}$	$A_{\cdot x,BL}$	$A_{\cdot g,RL}$	$A_{\cdot a,BS}$	$A_{\cdot i,BS}$	$A_{\cdot x,BS}$	$A_{\cdot g,RS}$
$A_{\cdot a,BL}$	1 193							
$A_{\cdot i,BL}$	0.8915* 193	1 193						
$A_{\cdot x,BL}$	0.9989* 193	0.8832* 193	1 193					
$A_{\cdot g,RL}$	0.9071* 122	0.9856* 122	0.9021* 122	1 122				

$A_{\cdot a,BS}$	0.4440* 48	0.5336* 48	0.4456* 48	0.6752* 48	1 48			
$A_{\cdot i,BS}$	0.5367* 48	0.6463* 48	0.4926* 48	0.7587* 48	0.7757* 48	1 48		
$A_{\cdot x,BS}$	0.2755 48	0.3549* 48	0.3093* 48	0.5139* 48	0.9421* 48	0.5627* 48	1 48	
$A_{\cdot g,RS}$	0.6680* 48	0.7719* 48	0.6745* 48	0.8620* 48	0.7738* 48	0.6933* 48	0.6470* 48	1 48
	Industry							
	$A_{\cdot a,BL}$	$A_{\cdot i,BL}$	$A_{\cdot x,BL}$	$A_{\cdot g,RL}$	$A_{\cdot a,BS}$	$A_{\cdot i,BS}$	$A_{\cdot x,BS}$	$A_{\cdot g,RS}$
$A_{\cdot a,BL}$	1 132							
$A_{\cdot i,BL}$	0.9142* 132	1 132						
$A_{\cdot x,BL}$	0.9900* 132	0.8712* 132	1 132					
$A_{\cdot g,RL}$	0.9756* 132	0.9651* 132	0.9547* 132	1 132				
$A_{\cdot a,BS}$	1.0000* 132	0.9142* 132	0.9900* 132	0.9756* 132	1 132			
$A_{\cdot i,BS}$	0.9142* 132	1.0000* 132	0.8712* 132	0.9651* 132	0.9142* 132	1 132		
$A_{\cdot x,BS}$	0.9900* 132	0.8712* 132	1.0000* 132	0.9547* 132	0.9900* 132	0.8712* 132	1 132	
$A_{\cdot g,RS}$	0.9756* 132	0.9651* 132	0.9547* 132	1.0000* 132	0.9756* 132	0.9651* 132	0.9547* 132	1 132
	Community, education							
	$A_{\cdot a,BL}$	$A_{\cdot i,BL}$	$A_{\cdot x,BL}$	$A_{\cdot g,RL}$	$A_{\cdot a,BS}$	$A_{\cdot i,BS}$	$A_{\cdot x,BS}$	$A_{\cdot g,RS}$
$A_{\cdot a,BL}$	1 190							
$A_{\cdot i,BL}$	0.9607* 190	1 190						
$A_{\cdot x,BL}$	0.8402* 190	0.7385* 190	1 190					
$A_{\cdot g,RL}$	0.3268* 190	0.3307* 190	0.2987* 190	1 190				

$A_{\cdot a,BS}$	0.9472* 190	0.9048* 190	0.8291* 190	0.2870* 190	1 190			
$A_{\cdot i,BS}$	0.8874* 190	0.9085* 190	0.7152* 190	0.2589* 190	0.9517* 190	1 190		
$A_{\cdot x,BS}$	0.8378* 190	0.7387* 190	0.9627* 190	0.2916* 190	0.8380* 190	0.7181* 190	1 190	
$A_{\cdot g,RS}$	0.3323* 190	0.3410* 190	0.3067* 190	0.9978* 190	0.2905* 190	0.2653* 190	0.2998* 190	1 190
Potential	Government							
	$P_{\cdot a,BL}$	$P_{\cdot i,BL}$	$P_{\cdot x,BL}$	$P_{\cdot g,RL}$	$P_{\cdot a,BS}$	$P_{\cdot i,BS}$	$P_{\cdot x,BS}$	$P_{\cdot g,RS}$
$P_{\cdot a,BL}$	1 179							
$P_{\cdot i,BL}$	0.7388* 179	1 193						
$P_{\cdot x,BL}$	0.8361* 179	0.3456* 179	1 179					
$P_{\cdot g,RL}$	0.8229* 130	0.6995* 130	0.6678* 130	1 130				
$P_{\cdot a,BS}$	0.5849* 94	0.6032* 95	0.3033* 94	0.5204* 78	1 95			
$P_{\cdot i,BS}$	-0.1135 47	0.2312 48	-0.1724 47	-0.1043 43	0.7047* 43	1 48		
$P_{\cdot x,BS}$	0.6136* 94	0.4162* 95	0.4428* 94	0.6029* 78	0.5572* 95	-0.129 43	1 95	
$P_{\cdot g,RS}$	0.8229* 130	0.6995* 130	0.6678* 130	1.0000* 130	0.5204* 78	-0.1043 43	0.6029* 78	1 130
	Industry							
	$P_{\cdot a,BL}$	$P_{\cdot i,BL}$	$P_{\cdot x,BL}$	$P_{\cdot g,RL}$	$P_{\cdot a,BS}$	$P_{\cdot i,BS}$	$P_{\cdot x,BS}$	$P_{\cdot g,RS}$
$P_{\cdot a,BL}$	1 140							
$P_{\cdot i,BL}$	0.6903* 140	1 140						
$P_{\cdot x,BL}$	0.9314* 140	0.5026* 140	1 140					
$P_{\cdot g,RL}$	0.5995*	0.3892*	0.5655*	1				

	140	140	140	185				
$P_{\cdot a,BS}$	0.6605* 75	0.3933* 75	0.5784* 75	0.5630* 75	1 75			
$P_{\cdot i,BS}$	0.4235* 75	0.4661* 75	0.3194* 75	0.5047* 75	0.6986* 75	1 75		
$P_{\cdot x,BS}$	0.6016* 75	0.1541 75	0.6613* 75	0.4253* 75	0.7962* 75	0.3199* 75	1 75	
$P_{\cdot g,RS}$	0.3601* 126	0.4873* 126	0.2473* 126	0.2921* 133	0.2870* 75	0.3078* 75	0.1418 75	1 133
	Community, education							
	$P_{\cdot a,BL}$	$P_{\cdot i,BL}$	$P_{\cdot x,BL}$	$P_{\cdot g,RL}$	$P_{\cdot a,BS}$	$P_{\cdot i,BS}$	$P_{\cdot x,BS}$	$P_{\cdot g,RS}$
$P_{\cdot a,BL}$	1 175							
$P_{\cdot i,BL}$	0.9584* 175	1 175						
$P_{\cdot x,BL}$	0.9783* 175	0.9025* 175	1 175					
$P_{\cdot g,RL}$	0.9246* 175	0.8845* 175	0.8984* 175	1 186				
$P_{\cdot a,BS}$	0.9466* 155	0.9032* 155	0.9218* 155	0.9217* 157	1 157			
$P_{\cdot i,BS}$	0.7705* 155	0.7905* 155	0.7107* 155	0.7332* 157	0.7954* 157	1 157		
$P_{\cdot x,BS}$	0.8864* 155	0.8166* 155	0.8930* 155	0.8574* 157	0.9570* 157	0.6481* 157	1 157	
$P_{\cdot g,RS}$	0.8951* 175	0.8559* 175	0.8669* 175	0.9727* 184	0.9323* 157	0.7250* 157	0.8863* 157	1 184

6.0 Conclusions and future directions

The *A* and *P* indices should be considered works in progress. Their purpose is first to spur discussion and further development of measures of this important aspect of the global IT industry. Second, the indices facilitate for others the exploration of potential impacts of open source software and approaches at a country level. An important next step—and test—for the index lies in its use by policy makers, industry, and others in crafting strategies and policies for the advancement of open source interests and ICT development more broadly.

Until now, much of the OSS domain is dominated by anecdotal and informal knowledge, especially about the state of OSS on a global scale. The *A* and *P* indices represent an important first step in advancing discussions about global OSS development by providing systematic and robust empirical evidence on a global scale. To do so, we confronted head-on the difficulties in constructing useful indices for such a tricky concept as OSS activity or potential. Our efforts attempt to reflect the openness and transparency of the OSS enterprise, thus our methods are described in detail here and the base data are readily available for download by the broader "user community" for this research. While we believe that the indices presented here provide a good "snapshot" of a country's open source potential and activity, it is worth noting that better data collection—beyond the scope of the current project—could improve the index in subsequent iterations. We welcome continued improvements to and adaptations of these indices.

Turning to policy considerations, government commissions and agencies have proposed, and in some cases implemented, a variety of measures to encourage open source developers. For example, in the United States, the President's Information Technology Advisory Committee (2000) recommended direct federal subsidies for open source projects to advance high-end computing, and a report from the European Commission (2001) also discussed support for open developers and standards. Many European governments have policies to encourage the use and purchase of open source software for government use. As is well known, governments can sponsor the development of localized open source projects. Economists have sought to understand the consequences of a vibrant open source sector for social welfare. Perhaps not surprisingly, definitive or sweeping answers have been difficult to come by. But if a tentative conclusion can be made, most analyses have concluded, based on limited data, that government support for open source projects is likely to have an ambiguous effect on social welfare.

We hope that these indices are not the end product of research in this area, but rather the beginning of an empirical research agenda at the intersection of OSS and public policy. Future research could make use of these indices to test a variety of hypotheses about the causes and effects of OSS and related policies. Anecdotal evidence, case studies, and intuitions pervade the OSS discourse. Thus far, much of the literature has very limited generalizability because of the prevalence of case-study approaches. The OSS indices presented here can help bring light where there is much heat. For example, the frequent claims about OSS's liberating nature and positive implications for social welfare (made often by governments themselves) lack a strong empirical basis. Future research can use these OSS indices to systematically assess the societal impacts of effects of OSS. The indices can enable testing of hypotheses about whether OSS drives innovation, economic development, transparency in governance, or other social aims. These indices can also play pivotal roles in studies of the rise of OSS activity. Identifying the determinants of OSS activity, and the factors that influence which countries achieve more of their OSS potential, merits additional investigation.

If “footloose” developers can participate in OSS projects across boundaries, what role does the state and geography more generally have in guiding the evolution of OSS? The OSS indices can inform studies of the effectiveness of particular OSS policies and initiatives on developing OSS, of strategic interdependence between states in setting their OSS policy (akin to trade policy), of the influences of different political and cultural landscapes on the popularity of OSS, and of the impact of education programs on OSS. Knowing where the cathedrals and bazaars are will hopefully launch a new set of inquiries into the determinants of that distribution and the implications of greater OSS activity and potential.

7.0 Appendix

7.1 Variable List

Variables in Index A and Index P	Indicator	Source
OSSpolNatman	Count of policies at the national level that mandate open source software	Center for Strategic and International Studies “Government Open Source Policies” 2008
GovExppGDP	Government expenditures as percent gross domestic product	World Development Indicators 2003
OSSpolNatRD	Count of policies at the national level that provide R&D for open source software	Center for Strategic and International Studies “Government Open Source Policies” 2008
OSSfundng	Ratio of national and local R&D policies to all national and local policies	derived from Center for Strategic and International Studies 2008
RHCEpc	number of Red Hat Certified Engineers	Red Hat, Inc. 2008
LinuxUserspc	Number of GNU/Linux users registered per capita	Linux Counter 2008
GoogleApppc	Number of applications submitted to Google Summer of Code per capita	Google Summer of Code 2005
SchoolNet	Percent schools connected to Internet	CIA World Fact Book 2004
rOSSnews	Number of hits for “open source software” on Google News archives within country during 2008	Google News 2008
LinuxLang	1 if native language support for GNU/Linux, 0 if otherwise	Distro Watch
nPiracy	Number of pirated software units divided by total number of units put into use, negative transform	Business Software Alliance 2006
OOXML	-1 if country voted for OOXML passage, 0 if No, empty if abstained or not invited	Open Malaysia Blog, ISO 2008
nCivLib	Freedom in the World Index of Civil Liberties scored 1 through 7, higher being worse, negative transform	Freedom House 2006
Turnout	Percent voters of voting age population (1945 to 1998)	International IDEA
eGov	e-Government Survey Score	United Nations 2008
nTRIPS	-1 if participant of TRIPS (Trade Related Aspects of Intellectual Property)	World Trade Organization 2008
nIPRI	Intellectual Property RIghts Index, higher score indicates more rights, negative transform	Property Rights Alliance 2008
ICTtop250pGDP	Number of ICT firms in the Top 250 per gross domestic product	OECD 2005
ICTexpendpGDP	ICT expenditures as percent gross domestic product	CIA World Fact Book 2004

newCellGro	Growth of number of cell phones from 1995 to 2001, percent growth over baseline year	World Development Indicators 2001
TelecomInvestpc	Private investment in telecoms (current US$) per capita	International Telecommunications Union 2001
SciArticlespc	Number of published scientific and technical journal articles per capita	World Development Indicators 1999
RnDemploypc	Scientists and engineers per capita	World Development Indicators 2000
nNetPrice	Price basket for Internet service per month, negative transform	CIA World Fact Book 2003
inewGrowth	Growth of Foreign Direct Investment from 2001 to 2006, percent growth over baseline year	United Nations Conference on Trade and Development
TVpc	Number of television sets per capita	World Development Indicators 2000
Techphob	Percent students who consider themselves technophobic	Computers in Human Behavior 1995
College	Percent of college aged population enrolled	World Development Indicators 2000
GradEngpgrad	Graduates in engineering, manufacturing and construction (% of total graduates, tertiary)	World Development Indicators 2000
PCspc	Number of personal computers per capita	International Telecommunications Union 2004
InternetUserspc	Number of Internet users per capita	International Telecommunications Union 2004
Awa Variables		
rOSShits	Hits for "open source software" on Google by region=country	Google 2008
GDPpcPPP	Gross domestic product per capita adjusted purchasing power parity	2002
PCpc	Personal computers per capita	International Telecommunications Union 2004
XPpGDPPm	Cost of Windows XP in "gross domestic product months"	First Monday – Ghosh
iServerspc	Internet servers per capita	CIA World Fact Book 2005
InternetHostspc	Computers connected to Internet per capita	Computers in Human Behavior 2007
OSSpolNat and (d)	Two variables were created as a count of all National and Municipal level policies. These variables were further subdivided to create counts of policies that indicated just Mandates, Preferences, Advisorys, or R&D. This resulted in 10 variables. For each count variable, a dummy variable was created indicating 0 if no policy, 1 if one or more. Therefore, 20 policy variables total were available.	Center for Strategic and International Studies "Government Open Source Policies" 2008
OSSpolMun and (d)		
OSSpolNatRD and (d)		
OSSpolMunRD and (d)		
OSSpolNatadv and (d)		
OSSpolNatman and (d)		
OSSpolNatpre and (d)		
OSSpolMunadv and (d)		
OSSpolMunman and (d)		
OSSpolMunpre and (d)		
Pwa Variables		
Age2529%	Persons age 25 to 29 as percent population	CIA World Fact Book 2005

Age2024%	Persons age 20 to 24 as percent population	CIA World Fact Book 2005
Age1524%	Persons age 15 to 24 as percent population	CIA World Fact Book 2005
TVpc	Television sets per capita	World Development Indicators 2001
urban%	Percent population residing in urban area	2002
Literacy%	Percent population 15 and older who are literate	
HSenroll%	Percent eligible population enrolled in high school	World Development Indicators 2002
HSvoc	Enrollment in upper secondary technical/vocational programs	OECD 2005
newspc	Number of daily newspapers per capita	2000
InternetUserspc	Number of Internet users per capita	International Telecommunications Union 2004
Phonespc	Telephone landlines per capita	World Development Indicators 2001
Radiopc	Radio sets per capita	World Development Indicators 2001
Cellspc	Cellular phones per capita	World Development Indicators 2001
PhoneUSA	Average cost of telephone call to US (US$ per three minutes)	World Development Indicators 2001
PhoneLoc	Telephone average cost of local call (US$ per three minutes)	World Development Indicators 2001
Phonelinespc	Telephone mainlines in largest city (per 1,000 people)	World Development Indicators 2001
Phonelinespworker	Telephone mainlines per employee	World Development Indicators 2001
PhoneWaittime	Telephone mainlines, waiting time (years)	World Development Indicators 2000
Phonepc	Fixed line and mobile phone subscribers (per 1,000 people)	World Development Indicators 2001
nNetPrice	Price basket for Internet service per month, negative transform	CIA World Fact Book 2003
GDPpc	Gross domestic product per capita	World Development Indicators 2003
TradepGDP	Trade as percent of gross domestic product	World Development Indicators 2003
ICTpExport	Communications, computer, etc. (% of service exports, BoP)	World Development Indicators 2002
SciArticlespc	Number of scientific or technical journal articles published per capita	World Development Indicators 1999
POiGov	PO offers electronic services, percent of 12 potential services	Original data collection
POInternet	Post Office provides public Internet access points (1=yes, 0=no)… year=2005 or most recent if missing	Original data collection
nWTO	-1 if member of World Trade Organization	World Trade Organization 2007

7.2 Complete Index Values

Table A2: Select index ranks for all countries

Country	$A_{aa,BL}$	$A_{aa,BS}$	$A_{ag,RL}$	$A_{ag,RS}$	$P_{aa,BL}$	$P_{aa,BS}$	$P_{ag,RL}$	$P_{ag,RS}$	$Ratio_{aa,BL}$	$Ratio_{ag,RL}$	$Ratio_{aa,BS}$	$Ratio_{ag,RS}$	A_{wa}	P_{wa}
Afghanistan	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Albania	.	.	.	.	41	.	9	54	.	.	.	.	93	6
Algeria	99	.	92	.	86	.	97	94	38	81	.	.	88	.
Andorra	.	.	.	.	.	.	14	.	.	.	.	.	.	.
Angola	.	.	.	.	132	.	.	.	.	.	.	.	99	65
Antigua and Barbuda	.	.	.	.	.	.	4	.	.	.	.	.	.	.
Argentina	39	42	36	32	49	.	7	21	8	40	.	29	32	30
Armenia	101	.	.	.	.	.	.	.	.	.	.	.	98	.
Australia	13	10	22	25	10	13	15	29	36	23	13	22	12	9
Austria	34	16	51	37	15	14	21	43	65	48	18	33	29	13
Azerbaijan	129	.	47	.	99	.	.	.	21	.	.	.	.	45
Bahamas	62	.	33	.	.	.	17	.	.	33	.	.	.	.
Bahrain	58	.	60	.	.	.	.	.	.	.	.	.	58	.
Bangladesh	84	.	87	.	105	58	114	85	64	77	.	.	110	70
Barbados	88	.	.	.	.	.	48	.	.	.	.	.	52	.
Belarus	72	.	84	.	28	.	.	.	87	.	.	.	.	15
Belgium	3	13	10	23	18	16	25	42	11	14	10	17	1	8
Belize	.	.	.	.	72	.	57	.	.	.	.	.	56	.
Benin	.	.	.	.	109	.	121	87	.	.	.	.	108	71
Bhutan	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Bolivia	83	.	45	.	78	43	40	59	29	42	.	.	94	49
Bosnia and Herzegovina	66	.	.	.	.	.	.	.	.	.	.	.	.	.
Botswana	128	.	86	.	43	.	104	75	102	75	.	.	78	56
Brazil	5	32	4	17	55	46	68	45	2	1	30	15	10	.
Brunei Darussalam	65	.	.	.	.	.	.	.	.	.	.	.	.	.
Bulgaria	22	23	16	9	47	29	53	56	5	11	5	5	15	26
Burkina Faso	.	.	.	.	124	.	126	82	.	.	.	.	118	.
Burundi	.	.	.	.	129	.	.	.	.	.	.	.	.	72
Cambodia	123	.	.	.	127	.	102	.	48	.	.	.	75	.
Cameroon	107	.	48	.	126	.	113	80	66	43	.	.	101	64
Canada	33	24	53	39	6	8	13	27	76	52	22	35	24	.
Cape Verde	.	.	.	.	.	.	91	.	.	.	.	.	.	.
Central African Republic	.	.	.	.	138	.	.	.	.	.	.	.	.	.
Chad	.	.	.	.	136	.	.	.	.	.	.	.	.	.
Chile	28	.	40	.	48	33	62	50	6	35	.	.	20	28
China, People's Republic of	15	22	6	12	66	48	.	.	106	.	32	.	28	.
Columbia	36	.	.	.	60	27	83	63	103	.	.	.	25	33
Comoros	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Congo, Democratic Republic of the	105	.	101	.	130	60	.	.	72	.	.	.	.	.
Costa Rica	59	44	46	30	52	32	58	58	95	41	31	27	53	32
Croatia	53	26	58	42	46	.	55	4	85	51	.	40	61	23
Cuba	68	.	.	.	98	.	.	.	70	.	.	.	.	.
Cyprus	50	31	57	41	37	.	44	12	82	50	.	39	48	.
Czech Republic	47	.	56	.	40	25	60	5	73	46	.	.	41	.
Côte d'Ivoire (Ivory Coast)	108	.	99	.	115	.	.	.	62	.	.	.	100	.
Denmark	9	9	17	20	4	7	8	31	30	21	16	19	4	.
Djibouti	112	.	.	.	.	.	124	.	.	.	.	.	.	.

Dominica	.	.	.	.	.	.	81	.	.	.	.	.	49	.
Dominican Republic	97	.	79	.	73	.	36	74	15	73	.	.	.	.
Ecuador	80	.	.	.	65	54	86	70	10	.	.	.	87	51
Egypt	77	.	82	.	64	49	101	88	13	66	.	.	89	43
El Salvador	90	.	81	.	85	45	56	30	42	72	.	.	83	.
Equatorial Guinea	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Eritrea	131	.	.	.	.	.	.	.	.	.	.	.	.	.
Estonia	20	.	30	.	20	.	26	15	27	28	.	.	42	11
Ethiopia	100	.	100	.	.	.	.	.	.	.	.	.	121	68
Fiji	118	.	70	.	101	.	90	47	28	59	.	.	70	.
Finland	10	2	18	5	8	6	18	24	26	20	4	9	5	4
France	2	7	1	3	16	12	23	34	14	2	7	6	17	.
Gabon	.	.	.	.	117	.	.	.	.	.	.	.	82	.
Gambia	111	.	.	.	112	.	119	99	61	.	.	.	.	69
Georgia	.	.	.	.	57	.	74	90	.	.	.	.	.	.
Germany	21	15	20	28	17	15	1	13	33	24	14	25	27	12
Ghana	93	.	.	.	94	.	118	84	53	.	.	.	72	52
Greece	61	.	65	.	38	37	46	16	86	60	.	.	59	25
Grenada	.	.	.	.	54	.	75	.	.	.	.	.	51	.
Guatemala	91	.	.	.	95	.	106	89	56	.	.	.	86	53
Guinea	.	.	.	.	133	.	.	.	.	.	.	.	.	.
Guinea-Bissau	.	.	.	.	135	.	.	.	.	.	.	.	.	.
Guyana	.	.	.	.	84	.	80	81	.	.	.	.	.	.
Haiti	103	.	98	.	137	.	115	102	78	85	.	.	.	.
Honduras	104	.	.	.	96	52	99	86	46	.	.	.	95	61
Hong Kong	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Hungary	45	.	34	.	29	23	41	14	67	30	.	.	50	19
Iceland	4	1	35	31	19	.	22	1	12	36	.	31	3	.
India	29	29	27	24	79	59	96	71	98	4	27	11	35	60
Indonesia	70	41	85	46	81	44	84	78	50	71	1	41	90	.
Iran, Islamic Republic of	.	.	.	.	62	57	77	83	.	.	.	.	31	38
Iraq	71	.	.	.	.	.	.	.	.	.	.	.	.	.
Ireland	23	5	19	2	21	19	31	37	37	16	2	3	13	.
Israel	38	14	9	11	14	.	28	22	75	12	.	14	30	17
Italy	16	17	13	16	26	18	27	44	19	15	12	13	16	10
Jamaica	.	.	.	.	75	35	73	68	.	.	.	.	77	.
Japan	19	.	.	.	13	4	20	20	43	.	.	.	22	3
Jordan	60	.	66	.	77	42	92	46	74	54	.	.	84	42
Kazakhstan	125	.	80	.	67	.	34	36	4	74	.	.	.	.
Kenya	117	.	44	.	104	50	.	.	34	.	.	.	107	63
Kiribati	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Kuwait	81	.	69	.	51	.	45	67	101	61	.	.	62	.
Kyrgyzstan	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Laos (Lao People's Democratic Repub..	132	.	.	.	100	.	.	.	22	.	.	.	111	.
Latvia	114	.	68	.	27	.	33	3	93	63	.	.	54	16
Lebanon	85	.	74	.	.	.	61	.	.	68	.	.	76	.
Lesotho	.	.	.	.	89	.	94	64	.	.	.	.	.	55
Liberia	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Libya (Libyan Arab Jamahiriya)	89	.	.	.	.	.	.	.	.	.	.	.	.	.
Liechtenstein	.	.	.	.	.	.	3	.	.	.	.	.	.	.
Lithuania	76	.	29	.	35	.	43	7	90	26	.	.	46	29
Luxembourg	44	.	55	.	25	.	35	.	77	49	.	.	21	.

Macedonia, Former Yugoslav Republic..	64	.	.	.	.	.	.	.	.	.	.	.	.	35
Madagascar	.	.	.	.	119	.	105	98	.	.	.	.	114	.
Malawi	.	.	.	.	116	.	.	.	.	.	.	.	120	.
Malaysia	43	37	23	26	39	21	49	26	40	13	24	23	67	20
Maldives	74	.	67	.	.	.	89	.	.	55	.	.	.	.
Mali	.	.	.	.	114	.	128	.	.	.	.	.	116	.
Malta	49	.	38	.	.	.	37	.	.	38	.	.	45	.
Marshall Islands	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Mauritania	.	.	.	.	118	.	.	.	.	.	.	.	106	.
Mauritius	116	.	64	.	53	.	59	60	105	57	.	.	64	31
Mexico	54	.	42	.	56	38	67	51	100	34	.	.	63	36
Micronesia, Federated States of	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Moldova	127	.	83	.	33	.	.	.	97	.	.	.	105	34
Monaco	37	.	.	.	.	.	.	.	.	.	.	.	.	.
Mongolia	.	.	.	.	.	.	70	41	.	.	.	.	104	46
Montenegro	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Morocco	102	.	93	.	93	55	100	79	45	82	.	.	92	44
Mozambique	124	.	.	.	113	.	.	.	41	.	.	.	.	.
Myanmar	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Namibia	120	.	78	.	92	.	93	95	20	67	.	.	81	.
Nauru	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Nepal	119	.	75	.	110	.	111	96	39	62	.	.	117	.
Netherlands	17	8	11	19	7	11	10	33	47	19	11	18	11	.
New Zealand	25	.	32	.	11	20	16	32	60	32	.	.	19	.
Nicaragua	.	.	.	.	103	.	98	.	.	.	.	.	.	.
Niger	.	.	.	.	134	.	127	105	.	.	.	.	119	73
Nigeria	115	.	.	.	120	.	109	91	54	.	.	.	112	.
North Korea (Korea, Democratic Peop..	79	.	.	.	.	.	.	.	.	.	.	.	.	.
Norway	6	4	15	13	3	5	6	28	25	22	8	16	2	2
Oman	92	.	72	.	68	.	.	.	9	.	.	.	.	.
Pakistan	42	25	12	6	106	.	78	76	91	3	.	1	36	59
Palau	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Panama	86	.	73	.	71	39	82	11	16	65	.	.	66	48
Papua New Guinea	113	.	95	.	107	.	110	100	57	80	.	.	96	.
Paraguay	55	34	26	8	87	.	88	61	81	5	.	2	33	47
Peru	12	45	43	34	69	41	71	65	107	39	34	30	7	.
Philippines	69	46	25	15	76	40	79	73	32	8	33	4	40	.
Poland	40	21	54	40	30	24	42	8	44	47	6	37	44	22
Portugal	35	27	61	44	32	28	39	49	35	56	19	38	34	21
Qatar	8	.	.	.	.	.	.	.	.	.	.	.	.	.
Romania	63	.	63	.	45	26	47	23	89	58	.	.	71	.
Russian Federation	48	.	31	.	34	30	52	48	80	27	.	.	79	24
Rwanda	.	.	.	.	131	.	.	.	.	.	.	.	.	.
Saint Kitts and Nevis	.	.	.	.	.	.	72	.	.	.	.	.	.	.
Saint Lucia	.	.	.	.	.	.	51	.	.	.	.	.	.	.
Saint Vincent and the Grenadines	.	.	.	.	.	.	85	.	.	.	.	.	.	.
Samoa	121	.	.	.	.	.	.	.	.	.	.	.	68	.
San Marino	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Sao Tome and Principe	.	.	.	.	.	.	63	.	.	.	.	.	.	.
Saudi Arabia	82	.	.	.	70	.	.	.	18	.	.	.	74	50
Senegal	95	.	90	.	97	.	117	52	52	78	.	.	102	62
Serbia	75	.	.	.	.	.	.	.	.	.	.	.	.	.

Seychelles	.	.	.	.	36	.	64	.	.	.	.	.	.	.
Sierra Leone	.	.	.	.	123	.	125	104	.	.	.	.	.	.
Singapore	24	18	52	38	24	.	2	9	31	53	.	36	23	.
Slovakia	51	30	59	43	31	.	.	.	83	.	.	.	43	18
Slovenia	30	12	49	35	23	.	30	10	55	44	.	34	38	.
Solomon Islands	.	.	.	.	.	.	116	77	.	.	.	.	.	.
Somolia	109	.	.	.	.	.	.	.	.	.	.	.	.	.
South Africa	32	28	7	7	61	56	.	.	104	.	28	.	37	40
South Korea (Korea, Republic of)	31	36	14	21	12	1	19	6	69	18	23	24	39	5
Spain	1	19	3	14	22	17	29	40	7	6	15	12	6	14
Sri Lanka	73	40	41	33	91	.	95	62	59	31	.	28	57	.
Sudan	94	.	88	.	122	.	122	103	71	76	.	.	.	74
Suriname	.	.	.	.	88	.	54	.	.	.	.	.	.	.
Swaziland	.	.	.	.	108	.	.	.	.	.	.	.	.	.
Sweden	14	3	5	1	1	2	5	18	51	17	17	8	8	1
Switzerland	27	20	50	36	9	10	24	38	63	45	20	32	26	7
Syria	96	.	91	.	.	.	.	.	.	.	.	.	91	.
Taiwan (Republic of China)	11	.	.	.	.	.	.	.	.	.	.	.	.	.
Tajikistan	130	47	94	47	.	.	.	.	.	.	.	.	.	.
Tanzania	126	.	.	.	.	.	.	.	.	.	.	.	73	.
Thailand	46	43	24	27	74	47	76	57	96	9	3	20	55	39
Timor-Leste	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Togo	.	.	.	.	125	.	107	97	.	.	.	.	113	67
Tonga	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Trinidad and Tobago	87	.	71	.	59	34	38	25	3	64	.	.	65	41
Tunisia	56	.	37	.	90	53	87	66	79	29	.	.	85	54
Turkey	67	.	77	.	63	36	69	39	17	69	.	.	80	.
Turkmenistan	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Tuvalu	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Uganda	122	.	96	.	128	.	112	53	49	83	.	.	115	66
Ukraine	78	39	76	45	42	22	66	17	94	70	29	42	60	.
United Arab Emirates	52	.	62	.	44	.	.	.	84	.	.	.	.	.
United Kingdom (of England, Scotlan..	7	6	2	4	5	9	12	35	24	7	9	7	9	.
United States of America	18	11	28	22	2	3	11	19	58	25	21	21	14	.
Uruguay	57	38	39	29	50	31	50	69	88	37	26	26	69	27
Uzbekistan	106	.	.	.	58	.	32	72	1	.	.	.	.	.
Vanuatu	.	.	.	.	83	.	108	2	.	.	.	.	.	.
Vatican City	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Venezuela	26	35	21	18	82	51	65	55	99	10	25	10	18	37
Vietnam	41	33	8	10	102	.	.	.	92	.	.	.	47	.
Yemen	110	.	97	.	80	.	120	93	23	84	.	.	103	57
Zambia	.	.	.	.	111	.	123	101	.	.	.	.	109	58
Zimbabwe	98	.	89	.	121	.	103	92	68	79	.	.	97	.

7.3 References

Bitzer, Jürgen and Philip J.H. Schröder (eds), *The Economics of Open Source Software Development.* Elsevier. (2006).

Berry, David and Giles Moss, "Free and Open Source Software: Opening and Democratizing E-Government's Black Box," *Information Polity: The International Journal of Government and Democracy in the Information Age* 11, no. 1 (2006): 21-34.

Bonaccorsi, Andrea and Cristina Rossi. "Comparing Motivations of Individual Programmers andFirms to Take Part in the Open Source Movement: From Community to Business," *Knowledge, Technology & Policy* 18, no. 4 (Winter 2006): 40-64.

David, Paul A. and Joseph S. Shapiro. "Community-Based Production of Open Source Software: What Do We Know about the Developers Who Participate?" 20, no. 4 (2008): 364-398.

DiBona, Chris, Mark Stone, and Danese Cooper (eds), *Open Sources 2.0: The Continuing Evolution.* O'Reilly Media. (October 21, 2005).

Ebert, Udo and Heinz Welsch, "Meaningful Environmental Indices: A Social Choice Approach," *Journal of Environmental Economics and Management*, 47, no. 2 (2004): 270-283.

Feller, Joseph, Brian Fitzgerald, Scott A. Hissam, and Karim R. Lakhani (eds), *Perspectives on Free and Open Source Software.* MIT Press (2007).

Forge, Simon, "The Rain Forest and the Rock Garden: The Economic Impacts of Open Source Software," *Info: The Journal of Policy, Regulation and Strategy for Telecommunications, Information, and Media* 8, no. 3 (2006): 12-31.

Ghosh, Rishab Aiyer, *CODE: Collaborative Ownership and the Digital Economy*. MIT Press. (2006).

Ghosh, Rishab Aiyer, "Understanding Free Software Developers: Findings from the Floss Study," in Joseph Feller, Brian Fitzgerald, Scott A. Hissam, and Karim R. Lakhani, eds. *Perspectives on Free and Open Source Software*. Cambridge: MIT Press (2007): 23-45.

Gosain, Sanjay, "Looking Through a Window on Open Source Culture: Lessons for Community Infrastructure Design," *Systemes d'Information et Management* 8, no. 1 (2003): 11-42.

Hahn, R.W. (ed), *Government Policy toward Open Source Software*. AEI-Brookings Joint Center for Regulatory Studies: Washington DC. (2002).

Krishnamurthy, Sandeep, "On the Intrinsic and Extrinsic Motivation of Free/Libre/Open Source (FLOSS) Developers," *Knowledge, Technology & Policy* 18, no. 4 (Winter 2006): 17-39.

Lee, Jyh-An, "Government Policy toward Open Source Software: The Puzzles of Neutrality and Competition," *Knowledge, Technology & Policy* 18, no. 4 (Winter 2006): 113-141.

Lerner, Josh, and Jean Tirole, “The Scope of Open Source Licensing,” *Journal of Law Economics & Organization* 21, no. 1 (April 2005a): 20-56.

Lerner, Josh, and Jean Tirole, “The Economics of Technology Sharing: Open Source and Beyond,” *Journal of Economic Perspectives* 19, no. 2 (Spring 2005b): 99-120.

Lewis, James. “Government Open Source Policies.” Working Paper. Center for Strategic and International Studies. (July 2008).

Lin, Yuwei, “Hybrid Innovation: The Dynamics of Collaboration between the FLOSS Community and Corporations,” *Knowledge, Technology & Policy* 18, no. 4 (Winter 2006): 86-100.

Moon, Nathan, and Baker, Paul, “Adoption and Use of Open Source Software: Preliminary Literature Review,” Center for Advanced Communications Policy, Georgia Institute of Technology. Working Paper. (2009).

Raymond, Eric, *The Cathedral & the Bazaar: Musings on Linux and Open Source by an Accidental Revolutionary*. O’Reilly Media. (1999).

Simon, K. D., “The Value of Open Standards and Open-Source Software in Government Environments,” *IBM Systems Journal* 44, no. 2 (2005): 227-238

Seiferth, C. Justin, “Open Source and These United States,” *Knowledge, Technology & Policy* 12, no. 3 (Fall 1999): 50-79.

Vaisman, Daria, “Coding a Revolution,” *Foreign Policy* 159 (March/April 2007): 93.

Van Wendel de Joode, Ruben, Yuwei Lin, and Shay David, “Rethinking Free, Libre, and Open Source Software,” *Knowledge, Technology & Policy* 18, no. 4 (Winter 2006): 5-16.

Weber, Steven, *The Political Economy of Open Source Software,* BRIE Working Paper 140. (June 2000.)

Weber, Steven, *The Success of Open Source,* Harvard University Press. (2005).