Government Technology Policy, Social Value, and National Competitiveness

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Abstract

This study seeks to better understand the impact that government technology procurement regulations have on social value and national competitiveness. To do this, it examines the impact of a change in France's technology procurement policy that required government agencies to favor open source software (OSS) over proprietary software in an attempt to reduce costs creating an unexpected demand shock for OSS. Analysis using the rest of the EU as controls via difference-in-differences and synthetic control frameworks shows that this policy change led to an increase of nearly 600,000 OSS contributions per year from France, creating social value by increasing the availability and quality of free and open source software. Estimates indicate this would have cost paid software developers roughly $20 million per year to replicate. However, the open nature of such goods means that any country can reap the benefits of these efforts. Therefore, additional economic outcomes that enhance France's competitiveness are also considered. The results show that within France, the regulation led to a 0.6% - 5.4% yearly increase in companies that use OSS, a 9% - 18% yearly increase in the number of IT-related startups, a 6.6% - 14% yearly increase in the number of individuals employed in IT related jobs, and a 5% - 16% yearly decrease in software related patents. All of these outcomes help to increase productivity and competitiveness at the national level. In aggregate, these results show that changes in government technology policy that favor OSS can have a positive impact on both global social value and domestic national competitiveness.

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I. Introduction

In the modern economy, information technology (IT) plays an increasingly important role in productivity, competitiveness, and social welfare. Therefore, government policies related to IT are an important lever that policymakers can use to encourage growth within the economy. However, as IT evolves, so to must technology policy such that it reflects changes in how IT is developed. In particular, over the last decade IT in general, and software in particular is increasingly being developed by decentralized groups of individuals rather than through traditional vertically integrated firms. This phenomenon where software is produced via crowdsourcing and is often distributed for free is generally referred to as open source software (OSS) and it is playing an increasingly important role in the economy. For example, the iOS operating system on Apple's iPhone, Microsoft's Azure cloud computing framework, and most of the tools associated with big data and analytics are all built on OSS. Despite the significant contributions it is making to society, there have been few empirical studies of the impact of using or contributing to OSS. This is particularly the case when considering what role the government should play in sponsoring (or not sponsoring) contributions to such efforts. As a large purchaser of technology, one option available to governments is to favor OSS in its procurement contracts in hopes of inducing wider contribution to OSS.[2] However, increasing contribution levels alone may not have any positive impact on the country since OSS is open and the results of increased contributions (more and better-quality software) can be used by anyone. Therefore, this article seeks to answer two primary research questions. First, do country-level technology procurement regulations that favor the use of OSS have an impact on the level of contribution to OSS from that country? Second, are their measurable spillover effects that enhance the national competitiveness of that country?

Answering these two questions is of critical importance due to two important trends: governments are increasingly trying to reduce costs and they are increasingly trying to jumpstart technology related activity in their country. Governments are amongst the largest

[2] Government usage of technology procurement as a method for influencing the rate and direction of innovation and technological change has long been considered a viable option, although the actual results of this strategy can be mixed (Edler and Georghiou, 2007; Flamm, 1988; Langlois and Mowery, 1996; Mowery, 2010; Nemet, 2009).

purchasers of IT goods and services and comprise up to 27% of revenue for software firms (Lerner and Schankerman, 2010) and it has been argued that government use of OSS could lead to large cost savings (Varian and Shapiro, 2003). At the same time, governments are also interested in seeding technology industries to enhance the attractiveness of their countries for business investment and to increase their competitive advantage (Porter, 1990; Delgado, Ketels, Porter, and Stern, 2012). Prior research has shown that one way to do this that has large returns on investment is for governments to sponsor research and development (R&D) into OSS and other "digital dark matter" to help jumpstart their software ecosystem (Greenstein and Nagle, 2014). However, this method can require a large capital outlay to build R&D capacity. Therefore, if technology procurement regulations favoring OSS do indeed increase levels of contributions to OSS, which in turn can lead to positive economic outcomes that grow the technology sector within a country, then governments can kill two birds with one stone. From a national competitiveness standpoint, this spillover effect can be critical since inducing investments in OSS alone does not necessarily benefit the country itself in any meaningful way. By its nature, OSS is open and can be used by anyone. Therefore, if the country saves some money on technology costs, but leads its citizens to spend their time writing code that other countries can freely use without capturing any benefits, it is possible this strategy may be a poor one over the long term.

To answer the questions posed above, this study examines the impact of a French law that required government agencies to prefer OSS to proprietary software in their technology procurement efforts leading to an unexpected demand shock for OSS. Using OSS contribution data from GitHub, the primary repository for OSS projects worldwide, a difference-in-differences estimation is constructed to estimate the impact of the regulation on contributions to OSS by residents of France. 20 other OECD and EU member countries are used as controls in both a traditional regression estimation as well as a synthetic control framework (Abadie, Diamond, and Hainmueller, 2010). A placebo test is run using an Italian law that was very similar to the French law and was implemented at nearly the exact same time, but was never enforced and was largely ignored. After estimating the impact of the French law on contributions to OSS, spillover effects to other economic outcomes are considered. The impact of the law on firm usage of OSS, IT startup founding, IT labor, and software patents are examined using a variety of direct and indirect methods.

The results of this study show a large and significant increase in not only the number of contributions to OSS, but also the number of people contributing to OSS from France after the law goes into effect. The passage of the law led to an increase of between 50 and 57 thousand OSS contributions per month and between 67 and 245 new contributors to OSS that had never contributed before per month. These results hold when including various country-level control variables and using the synthetic control framework. Estimates indicate this would have cost paid software developers roughly $1.66 million per month to replicate. Further, the placebo test shows that Italy did not obtain the same benefits since the law was never enforced helping to rule out alternative explanations related to societal trends at the time. When considering the spillovers to other economic outcomes, a variety of positive indicators are found. After the passage of the law, the number of French companies that use OSS increases by between 0.6% and 5.4% per year. Prior research has shown that doing so can enhance their productivity and competitiveness (Nagle, 2019). Additionally, the number of IT-related startups founded increases by between 9% and 18% per year. Such firms have been shown to have a positive impact on economic growth (Audretsch, Keilbach, Lehmann, 2006). As a result of the regulation, the number of people employed in IT jobs in France increased by between 6.6% and 14% per year. IT labor increases have been shown to have positive effects on firm-level (and in turn national-level) productivity (Tambe and Hitt, 2012). Lastly, the implementation of the French regulation led to a *decrease* in software related patents by between 5% and 16% per year likely due to the embrace of open source principles. Although this may at first appear to be a negative outcome, many have argued that software patents diminish innovation and growth in the field (Bessen and Maskin, 2009; Hall and MacGarvie, 2010; Gambardella and von Hippel, 2017).

In aggregate, these results offer governments a significant and cost-effective policy lever that can be used to increase the OSS contributions made by their country, creating global social value. In turn, this increase in contributions leads to a variety of national benefits that help to increase the productivity and competitiveness of the country compared to others that do not make such regulatory changes to favor OSS in government procurement. These results are consistent with prior literature that has shown technology adoption can have positive benefits at firm and societal levels (e.g., Bartel, Ichniowski, and Shaw, 2007; Dittmar, 2011). The article proceeds as follows. Section II gives a brief background on OSS and the French law. Section III provides an overview of the data and the summary statistics. Section IV presents the empirical methodology, and section V presents the results of the law on OSS contribution. Section VI shows the results for the other economic outcomes and Section VII concludes.

II. Open Source Software and France's Circulaire 5608

Richard Stallman first introduced the concept of OSS in 1983 when he founded the GNU Project. The goal of GNU was to create a computer operating system that could be freely shared and modified by users. From these early efforts evolved a vast ecosystem of OSS including multiple operating systems, thousands of applications, and billions of lines of code.[3] Due to the lack of price frequently associated with OSS, it has long been a unique phenomenon of interest in the economics and management literature with a particular focus on why individuals and firms contribute to it (Kogut and Metiu, 2001; Lerner and Tirole, 2002; Lerner, Pathak, and Tirole, 2003; von Hippel and von Krogh, 2003; Lakhani and Wolf, 2005; Scotchmer, 2010; Athey and Ellison, 2014). Further, it has been posited that OSS could greatly benefit governments that implement it (Varian and Shapiro, 2003; Lerner and Schankerman, 2010), but prior work has not empirically examined the implications of such efforts.

In September 2012, Jean-Marc Ayrault, then the Prime Minister of France, signed into law Circulaire 5608[4] which provided a series of guidelines intended to promote the use of free and open source software within all of France's public administration departments. The directive was highly publicized and it required all departments to not only consider using

[3] For a rich history of OSS, Ran Levi has transcribed a series of interviews with Stallman here: https://www.cmpod.net/all-transcripts/history-open-source-free-software-text/.
[4] Available at http://circulaire.legifrance.gouv.fr/pdf/2012/09/cir_35837.pdf.

free and open alternatives when procuring new technology, but to also consider them when making major revisions to existing applications creating an unexpected shock to demand for OSS. The directive specifically states the possible benefits of using OSS as cost savings, minimizing unnecessary software development efforts, ensuring long-term support due to the open nature of the code, an opportunity to experiment and adapt the software after it was implemented, greater transparency allowing for better security, and increasing levels of competition amongst software providers. [5] Although this directive allowed the government users of such technology to contribute back to the creation of open source projects, an increase in contributions to OSS was not the goal of the regulation. However, as shown in Figure 1, there is a clear increase in the number of OSS contributions from France compared to 20 other European/OECD countries after Circulaire 5608 was signed into law. Further, there was no stated goal of creating spillover benefits that could enhance the national competitiveness of France other than by reducing government expenses. The intent of the regulation was purely to save costs for the central government through the variety of means mentioned above. Therefore, any resulting benefits to social value or the national economy can be considered unintentional.

III. Data and Summary Statistics

This section first discusses GitHub, the primary repository for OSS projects worldwide, to provide a clear background for the empirical setting and a discussion of how the variables of interest are measured. It then details the construction of the primary outcome variables of interest related to OSS contributions. Then the various control variables that will be used in the estimation are discussed. Summary statistics for all variables are provided.

III.A. Measuring OSS Contributions

The main data source for this study is GitHub, a web-based system for hosting software and maintaining accurate version control that was launched in early 2008. It is built on the

[5] In addition to these stated goals, one unstated goal was to decrease reliance on commercial software from the United States. However, there was no known goal (stated or otherwise) to improve the French technology industry, which is different than the overt protectionism sometimes seen in other countries, like Brazil's efforts to boost its microcomputer production in the 1990's (Luzio and Greenstein, 1995).

Git version control system originally designed in 2005 by Linus Torvalds, the creator of Linux. After its launch, GitHub quickly became the primary repository for OSS projects. From September 2016 to September 2017, people contributed over 1 billion OSS code commits to over 25 million public repositories.[6] Although GitHub can be used to host proprietary, closed-source software projects, the data collection process for this study gathered information exclusively for projects that are considered OSS and are freely available to the public.

Before individuals can make a contribution to an OSS project on GitHub, they must create a user profile. For roughly 50% of profiles, contributors include information about their location, including their country. Given geographic differences across the globe, and the interest in the impact of a regulation in France, data collection was limited to contributions made by individuals living in one of the 28 member countries of the European Union. Therefore, the dataset consists of contributions made by individuals living in the EU between the launch of GitHub in April 2008 and September 2016. This dataset consists of over 79 million commits. Due to the need for control variables (discussed below) that come from the Organization for Economic Co-operation and Development (OECD), the dataset is then limited to the 22 countries that are both members of the EU and the OECD, shown in Table 1. Further, since GitHub took some time to diffuse, the final dataset is truncated to start in January 2009.[7] This final dataset contains just over 62 million commits and is the primary dataset used for the study. Figure 2 shows a breakdown of commits by country.

Beyond just the raw number of commits that are made to OSS projects hosted on GitHub, questions are likely to arise related to the number and type of *people* that are contributing.

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[6] A commit is a portion of code that is generally only a few lines, but can be much larger. A repository is an OSS project, although projects can be "forked" such that one project has many copies, each of which are maintained by separate entities. Statistics from https://octoverse.github.com/ retrieved on November 14, 2017.

[7] It is important to note that while GitHub took some time to diffuse, there is no evidence this happened differently across the countries in this study. The one possible exception would be the United Kingdom since the primary coding language used across the world is English. However, this would bias against the results and robustness checks indicate that the results hold if the UK is removed from the control sample.

In particular, since recent work (Lerner, Pathak, and Tirole, 2006; Nagle, 2018) has shown that firms are increasingly paying their employees to contribute to OSS projects, it will be interesting to consider whether contributions are sponsored by an employer or not. Although getting this information directly is not feasible for the entire dataset, each commit includes a timestamp. This allows for commits to be split into two groups – working hours (8am-6pm Monday-Friday in the local time zone) and non-working hours (all other times). Although this measure is by no means perfect, it provides a reasonable proxy for understanding whether or not contributions are sponsored by a firm. Figure 3 shows the average number of contributions by country and day of the week, adding support to prior studies by showing there are 40% - 50% more contributions on weekdays compared to weekends. In addition to the number of contributions, the number of daily unique contributors is collected as well to get a measure of individual-level activity on a daily basis. Finally, since it is feasible that the mechanism through which any spillover effects may occur is by introducing new people to the software creation process, the number of new contributors (those who have never made an OSS contribution on GitHub before) is also collected and will be used to explore the spillover effect on other economic outcomes. Since analysis will occur at both the monthly and yearly level, Table 2 shows the summary statistics for contributions and contributors at both levels as well as the control variables (discussed below).[8]

III.B. Control Variables

Although all of the countries in the sample are in the EU and the OECD, the countries are still quite disparate along a variety of dimensions. Therefore, a battery of control variables is included in the specifications. Yearly population statistics are obtained from the World Bank. Total yearly GDP in Millions of USD comes from the OECD and is used to calculate GDP per Capita. Additional data on quarterly GDP growth from the OECD is included for models that are performed at the monthly level to account for fluctuations in output throughout the year. General government spending figures are represented as a percent of

[8] Table 2 indicates that the OSS contributions are right skewed. However, the variable is used in an untransformed manner in the primary analysis to allow for ease of interpretation. Results are consistent using a square-root, cube-root, or dual power (Yang, 2006) transformation to account for the skew in a count variable.

GDP and come from the OECD. Since access to the Internet is a prerequisite for contributing to GitHub, the percent of the population that has access to the Internet was gathered from the International Telecommunications Union (ITU).

In addition to this first set of control variables, additional controls for which data was not yet available for 2016 were collected. These include education statistics from the OECD presented as the percent of the population that have less than upper secondary education, the percent of the population that have upper secondary education, but not tertiary education, and the percent of the population that have tertiary education.[9] Data on the percent of the population with the Internet available at their home also comes from the OECD. This is slightly different than the ITU Internet availability, mentioned above, which focuses on general access rather than access at home. Although these numbers are correlated, the difference may be important given that a significant proportion of OSS commits are done by individuals at home (as discussed above) and that technology availability in the home has different effects than general technology availability (Malamud and Pop-Eleches, 2011). Finally, unemployment data is included as the official unemployment rate reported by the OECD. Table 2 shows the summary statistics for the various control variables.

IV. Empirical Methodology

This section details the empirical methodology employed to perform the analysis of the impact of the Circulaire 5608. First, it describes the primary research methodology implemented to construct difference-in-differences models to estimate the impact on OSS contribution related outcomes. Second, it discusses the synthetic control analysis that will be applied to allow for a more causal interpretation of the results. Finally, it presents the methods used for estimating other economic outcomes that occur as a result of the primary effects.

IV.A. Primary Research Design

[9] According to the OECD, upper secondary education is equivalent to high school in the US, and tertiary education is equivalent to college.

The first goal of this study is to understand the impact of the Circulaire 5608 on OSS contributions in France. Since the regulation was implemented at a discrete point in time and only impacted one country, a difference-in-differences estimation framework is used as follows:

$$Y_{it} = \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Post_t x Treated_i + \gamma_1 Z_{it} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the OSS contribution related outcome variable of interest (total number of contributions, number of work vs. non-work contributions, number of new contributors, and number of daily contributors) for country i at time t. $Treated_i$ is a binary variable that is 1 for a country where a law requiring the favoring of OSS in government procurement is implemented, and 0 otherwise. In the primary analysis, only France is marked as a 1 to reflect the implementation of the Circulaire 5608. In the placebo test discussed below, Italy is the only country marked as a 1 to reflect similar legislation they passed, but did not enforce (detailed below). To prevent contamination between these two countries, Italy is not included in the primary analysis and France is not included in the placebo test. $Post_t$ is a binary variable that is 1 if the current time period is after the passage of the Circulaire 5608, and 0 otherwise. For analysis at the monthly level, $Post_t$ is 1 starting in October 2012 and at the yearly level it is 1 starting in 2013. Z_{it} represents a battery of control variables that vary at the country-level by time period, as discussed above in Section III.B. $Post_t x Treated_i$ is the interaction of the two binary terms creating a third binary term that is 1 for France after the passage of the Circulaire 5608 and 0 otherwise. This allows the coefficient β_3 to be interpreted as the increase in the outcome variable Y that results from the passage of the regulation. All standard errors are heteroskedastic-robust and are clustered at the country level. To further control for differences across countries and time, two additional models are used as robustness checks:

$$Y_{it} = \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Post_t x Treated_i + \gamma_1 Z_{it} + \delta_t + \varepsilon_{it} \quad (2)$$

$$Y_{it} = \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Post_t x Treated_i + \gamma_1 Z_{it} + \delta_t + \theta_i + \varepsilon_{it} \quad (3)$$

where δ_t is a time fixed-effect and θ_i is a country-specific random effect.

IV.B. Synthetic Control Analysis

A known issue with measuring the impact of policy changes at the country level is that there is a great degree of variance between countries. Although the control variables help to address this concern, another option that helps to reduce model dependence and possible bias is the use of a synthetic control. Introduced by Abadie, Diamond, and Hainmueller (2010), the synthetic control is designed to be used in situations where there is one treated observation and many control observations, as is frequently the case in policy analysis. Although France is one of the larger economies in the EU, and is also one of the heaviest contributors to OSS, as seen in Figure 2, the economies of Germany and Great Britain are of comparable (or larger) size based on GDP during the study and these two countries consistently contribute more to OSS than France. Therefore, the synthetic control method can be applied to create a "synthetic France" that is a mix of other EU members to create a well-matched control that is as similar to France as possible, based on observables, in the pre-treatment period. As with the difference-in-differences estimates discussed above in Section IV.A, Italy is removed from the comparison set since it will be used as a placebo test. Robustness tests confirm that the results are the same if Italy is included as it is not actually used in the creation of the synthetic control (e.g., it has a weighting of 0).

IV.C. Measuring Other Economic Outcomes

As discussed above, if the implementation of the Circulaire 5608 is found to have a positive impact on the number of contributions and contributors to OSS in France, it remains unclear whether there is any economic benefit to France. If the only outcome is that there is more and better-quality OSS available, this benefit is not limited to France but can be used by all countries as OSS, by its nature, is open and freely available. However, existing literature has shown that individuals and firms can learn how to better use OSS by contributing to it (e.g., Lerner, Pathak, and Tirole, 2006; Nagle 2018), so there is likely some benefit that is obtained by France that does not accrue to free-riders. Given the granularity of the data, it is difficult to measure this direct learning effect at the country level. However, it is likely that other benefits may arise at the country level. In particular, an increase in OSS contributions and contributors may have an impact on the number of firms using OSS, the number of individuals employed in IT related jobs, the number of IT-related startups, and the number of software related patents. To understand this spillover effect, three methods will be employed to attempt to show that the shock leads to an increase in X (contributions/contributors), which in turn leads to an increase in Y (economic outcomes).

First, a simple regression will be run where the economic outcome variable is used as the dependent variable and the independent variable of interest is either the number of contributions in the country or the number of new contributors in the country. This will look as follows:

$$Y_{it} = \beta_1 X_{it} + \gamma_1 Z_{it} + \varepsilon_{it} \tag{4}$$

where Y_{it} is the economic outcome variable of firm usage of OSS, IT labor, new IT startups, or number of software patents in country i at time t, X_{it} is a measure of either the number of contributions or the number of new contributors in country i at time t, and Z_{it} is the set of control variables discussed above. Although this regression will not show the direct impact of the Circulaire 5608 on the outcome variable, if β_1 is positive and significant it will offer some evidence to support the causal chain.

Second, to get more directly at the impact of the Circulaire 5608 on the economic outcome variables a control function methodology, similar to that of two-stage least squares, will be used (Heckman and Robb, 1985). The first stage will be the same as Equation (1) above. Then, the predicted values for best fit ($\hat{X}_{it}$) will be calculated and the residuals from this estimate (e_{it}) will be calculated. Then, the following equation will be estimated:

$$Y_{it} = \beta_1 \hat{X}_{it} + \beta_2 e_{it} + \gamma_1 Z_{it} + \varepsilon_{it} \tag{5}$$

By definition, the residual e_{it} is orthogonal to the impact of the shock of the Circulaire 5608 and β_1 can then be interpreted as the impact of the regulation on the economic outcome variable of interest (Y_{it}) through the increased level of contribution ($\hat{X}_{it}$) that occurs because of the regulation.

Finally, a method suggested by Angrist and Pischke (2008) is used. Although it does not establish a causal effect, they point out it can be suggestive that the shock has an impact on Y_{it} via X_{it}. This involves estimating the two following equations:

$$Y_{it} = \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Post_t x Treated_i + \gamma_1 Z_{it} + \varepsilon_{it} \quad (6)$$

$$Y_{it} = \beta_1 Treated_i + \beta_2 Post_t + \beta_3 Post_t x Treated_i + \beta_4 X_{it} + \gamma_1 Z_{it} + \varepsilon_{it} \quad (7)$$

where Y_{it} is the economic outcome variable of firm usage of OSS, IT labor, new IT startups, or number of software patents in country i at time t and X_{it} is a measure of either the number of contributions or the number of new contributors in country i at time t. By estimating the difference-in-differences equation with the economic outcome variable as the dependent variable both with and without including the contribution measure, we can infer whether or not X_{it} plays a role in the impact on Y_{it} that occurs as a result of the regulatory shock. If β_3 is positive and significant in Equation (6), but in Equation (7), it is not and β_4 is positive and significant, then it can be inferred that the impact of the shock on Y_{it} occurs through an increase in X_{it}.

Independently, these three methods do not establish a causal mechanism from the regulatory shock to X_{it} and in turn to Y_{it}, but in aggregate, if all three tell a similar story, then a stronger case for this mechanism can be made.

V. The Effect of Circulaire 5608 on Open Source Software Contributions

This section presents the results of applying the empirical methodology to the data as discussed above. First, the results related to the number of commits are presented. Then, the results related to the number of contributors are presented. Finally, a placebo test is performed using an Italian law that was similar to the French Circulaire 5608, but was never enforced, to add weight to a causal interpretation of the results.

V.A. Impact on Number of Commits

Table 3 shows the results of the Circulaire 5608 on OSS commits to GitHub at the monthly level.[10] All columns use OLS models, except column 5, which uses a random effects analysis. Columns 1-4 use an increasing level of control variables, and all models use heteroskedastic-robust standard errors that are clustered at the country level. The interaction term of Treated x Post shows the additional number of OSS commits (in thousands per month) that occur in the treated country (France) after the introduction of the Circulaire 5608. In all models, this coefficient is positive and statistically significant at the 1% level indicating a substantial increase in the number of OSS commits per month in France after the law is passed. The lower bound on the coefficient across columns is 49.659 indicating an increase of 49,659 commits per month resulting from the implementation of the new law. This compares to an average of 31,634 commits per month across the entire sample. Table A.1 (in the appendix) shows similar results when performing the analysis at the yearly, rather than monthly, level. We can estimate the social value creation that results from this increase in contributions in a manner similar to that used in Ghosh (2006) by calculating the replacement cost that it would take a private firm to create this code. Although this methodology is not perfect, it is a standard process for valuing goods with no price (Nordhaus, 2006). First, the Constructive Cost Model II (COCOMO II) is used to estimate the number of person-months it would take to create this software.[11] If we assume that all 49,569 commits are only one line of code, then we can use this as the input into the COCOMO II process. Although this estimate of one line of code per commit is necessarily an underestimate, the modal number of lines of code per commit is generally 1. However, this can be considered a lower bound. The COCOMO II calculation with default parameters estimates that it would take 215.1 person-months of effort to write 49,569 lines of code. In the United States in 2013, the average median yearly salary for a software engineer was $92,820, which translates to $7,735/month.[12] This leads to an estimated value of the

[10] For reasons discussed in Section V.C. below, Italy is removed from the sample as it had a similar law passed at nearly the same time. Therefore, the number of observations is lower than that reported in the summary statistics. However, the results are robust to the inclusion of Italy in the control group.

[11] A discussion of the COCOMO II process, as well as a calculator for implementing it, can be found here: http://csse.usc.edu/tools/cocomoii.php. Accessed on November 17, 2017.

[12] US wage data is used due to lack of reliable data for programmers in France. The number reported is the May 2013 national average for Occupation code 15-1130, Software Developers and Programmers, available at https://www.bls.gov/oes/2013/may/oes_nat.htm.

contributions that are a result of Circulaire 5608 of $1.66 million each month after the regulation is implemented, or nearly $20 million per year. From the time Circulaire 5608 was implemented in September 2012 until the end of the GitHub data series in September 2016, this value aggregates to an overall creation of global social value by nearly $80 million.

Figures 4 and 5 show the results using the same data at the monthly level, but they use a synthetic control methodology with all controls used for pre-period matching. In Figure 4, the number of monthly commits from France are shown in blue and the number from the synthetic France are shown in red. The pre-shock fit of the model is good (RMSPE is 1.42) leading to nearly identical values in the pre-period where France averages 20, 656 commits per month and the synthetic France averages 20,659 commits per month. In the post period, the data show that in most months the number of commits from France is greater than those from the synthetic France. Figure 5 shows the same data, but calculates the difference between France and synthetic France (Treated minus Control). In the pre-period, the trend is nearly flat and all observations hover near zero. However in the post-period there is a visibly increasing trend line and nearly all observations are significantly above zero.

Classifying the commits into those made during work hours and those during non-work hours, as discussed above, yields deeper insights into whom the law impacts – contributors who are being paid to contribute by their employers, or those who are contributing on their own time. Table 4 shows these results at the monthly level. Columns 1-4 show the results for contributions during working hours (Monday-Friday, 8am-6pm local) and columns 5-8 show the results for contributions during non-working hours (all other times). Comparing the coefficients on Treated x Post across the two types of contributions yields a similar result to comparing the baseline averages for these two types of contributions from the summary statistics. This indicates that both types of contributors are increasing their number of commits at roughly the same pace. This is important as it shows the increase in contributions is not solely driven by those being paid by their employer, but by hobbyists as well. Table A.2 (in the appendix) shows similar results when performing the analysis at the yearly, rather than monthly, level. These results are robust to defining non-work hours as only Saturday and Sunday, and work hours as Monday – Friday. Both groups have a positive and significant increase, although the difference between the two is larger.[13] However, this difference is mechanical since there are 2.5 times as many weekdays as there are weekends.

V.B. Impact on Number of Contributors

The results from the analysis related to the number of commits lead to two related questions: Is the increase in commits driven by the same number of people contributing more, or by more people contributing? Is the increase in commits driven by existing contributors that had contributed previously, or is there an increase in the number of new people that had not contributed previously?

Table 5 shows the results when the outcome variable is the average number of contributors per day, aggregated at the monthly level. Across all columns, there is a positive and significant increase (at the 1% level) in the average number of daily contributors in France after the implementation of the Circulaire 5608. The lowest estimate of these coefficients is 401.903 indicating that on the average day in France after the implementation of the regulation, there are 402 more contributors than there would have been without the regulation. These results indicate that those from Section V.A above are not simply driven by an increase in the number of contributions made by each person at a given time, but instead that there are more people making contributions on a given day. Table A.3 (in the appendix) shows similar results when performing the analysis at the yearly, rather than monthly, level.

Perhaps even more interesting is the second question, as to whether or not the Circulaire 5608 simply induced existing contributors to contribute more frequently, or whether it led to new individuals contributing to OSS for the first time. Table 6 offers support for a case that it was the latter. At the monthly level, the results indicate the implementation of the regulation led to between 67 and 244 new contributors to OSS. Table A.4 (in the appendix) shows similar results when performing the analysis at the yearly, rather than monthly, level.

[13] Results not shown due to space constraints, available from the author upon request.

In aggregate, these results offer strong support for the implementation of the Circulaire 5608 substantially increasing the number of people from France that are contributing to OSS on a given day, and the number of people that are contributing for the first time.

V.C. Placebo Test – Italy's CAD Article 68

In August 2012, one month prior to the implementation of Circulaire 5608, Italy passed a very similar law, Codice Administrazione Digitale (CAD) Article 68. This law required government departments to consider OSS amongst their options when procuring technology. Proprietary software solutions were only allowed if it could be shown they would be cheaper than opting for an OSS solution. As with the law in France, the stated goal was to reduce government costs for software. However, unlike in France, CAD Article 68 was never enforced and was largely ignored by government administrators. To start with, as late as May 2013, nine months after the law was signed, the working group responsible for detailing how the cost comparison should be calculated had not issued any guidance and was accused of deliberately stalling the process (Hillenius, 2013). Perhaps an even more glaring example was that, as of February 2016, the department that had pushed for the law in the first place, the Agenzia per l'Italia Digitale (Agency for the Digitalization of the Public Sector) continued to ignore the mandate (Montegiove, 2016). Montegiove further argued that Article 68 is generally ignored because it lacks any method for monitoring or punishment. Italy's CAD Article 68 provides an excellent setting for a placebo test of the primary effect of France's Circulaire 5608. In policy analysis, placebo tests are generally performed by examining the impact of the law of interest in a country that did not implement the law. However, in this case, we can examine the impact of a law that was implemented at nearly exactly the same time, but was never enforced and largely ignored. This helps to rule out concerns that some unobserved underlying trend in France led to both Circulaire 5608 and the increase in contributions and contributors that followed. Arguably Italy would have the same unobserved underlying trend that led it to implement CAD Article 68 and if the increase in contributions and contributors was due to this trend, then it should still be apparent in Italy even though the law was ignored.

Table 7 shows the same specifications as Table 3 above, except that Italy is now considered the treated country and France is left out of the sample. Across all specifications at the monthly level, the coefficient on Treated x Post is not statistically distinguishable from zero at the 10% level. Table A.5 (in the appendix) shows similar results when performing the analysis at the yearly, rather than monthly, level. This finding adds substantial weight to the driving force behind the results discussed above being the implementation and enforcement of the Circulaire 5608. The implementation, but lack of enforcement and compliance, of a very similar law at nearly the exact same time in Italy has no measureable effect on the number of contributions to OSS. The results of this placebo test help to add weight to a causal interpretation of the impact of the Circulaire 5608 by helping to rule out underlying forces and trends that might lead to the introduction of such a law at that time. If there were any such trends, they were likely also occurring in Italy, but due to the way the Italian law was implemented, CAD Article 68 was not enforced and Italy received no resultant increase in OSS contributions.

VI. The Effect of Circulaire 5608 on Other Economic Outcomes

As mentioned above, the trouble with inducing investment in creating OSS is that the benefits (more and/or higher quality OSS) cannot be restricted to only the country that increases its level of investment. When France increases its amount of contribution to OSS, every other country in the world can utilize the output. Although this leads to a large contribution to global social value, it does not directly increase France's national competitiveness. Therefore, any possible benefits that are obtained only by France are now considered. In this section, outcomes related to firm usage of OSS, IT startups, IT labor, and software patents will be explored. Analysis is focused on these particular variables due to the likelihood they will be impacted by an increase in OSS contributions and contributors. As more individuals become aware of, and experienced with, OSS, there is an increase in the availability of OSS skills. This allows firms to increase their usage of OSS since they can more readily find the complementary labor skills to deploy and support it. The increase in availability of OSS and OSS skills discussed above also reduces the barriers to entry for new technology-related companies. IT costs can be a large expense when starting a tech company, but the free nature of OSS reduces these costs allowing for an increase in the number of IT startups. Relatedly, the increased exposure to OSS allows hobbyists and inexperienced programmers to gain practical experience programming as part of a team, rather than on their own. This would result in an increase in the availability of individuals with programming skills and could lead to an increase in IT labor.[14] Finally, OSS represents more than just the software code itself, it also represents a manner of thinking about intellectual property rights that is different than traditional patenting. It is quite feasible that the broader exposure to OSS found above was coupled with a broader exposure to alternative IP methods. Therefore, software developers might think twice about patenting their software which could result in a decrease in software patents coming from France. Table 8 presents summary statistics related to these economic outcome variables, although their precise construction is discussed in each relevant section below.

VI.A. OSS Usage

As discussed previously in Section V.A, many of the increased contributions that result from the Circulaire 5608 occur during work hours. Therefore, it is feasible to venture that there is a related rise in OSS usage by existing firms. A measure of such usage can be obtained from the Harte Hanks/Aberdeen Ci Technology Database (CiTDB), a large survey of IT usage across thousands of firms and their individual establishments. For example, in 2012, the survey collected data on 17,615 establishments in France. This survey is regularly used in studies of the economic impact of IT (Bresnahan, Brynjolfsson, and Hitt, 2002; Bloom, Sadun, and Van Reenen, 2012; Forman, Goldfarb, and Greenstein, 2012; McElheran, 2014) and is conducted at a sampling of establishments at each firm each year.

[14] A real-world example of someone who went through this process can help illustrate the feasibility of a causal chain. From 1998-2013, Frederic Bardeau (a French citizen) worked in the communications and public relations field. Although he had no IT experience, he performed consulting work for the French government. Therefore, it is likely that he would have been aware of the highly publicized Circulaire 5608. In March 2013, 6 months after the publication of Circulaire 5608, Bardeau created a GitHub account and began experimenting with OSS. One month later, Bardeau founded Simplon.co, a company that offers free training in digital technology and computer programming to disadvantaged populations including youth with little education, refugees, people with disabilities, and the long-term unemployed. Six months later, Bardeau left his primary job to go full-time at Simplon.co. Therefore, not only does Bardeau appear in the GitHub data in the first stage as a new contributor to OSS, but he would also appear in the second stage as the founder of an IT company and an individual with a job in IT. Further, due to the nature of the company he founded, many more individuals would eventually enter the IT labor force.

The survey asks each establishment about their use of IT, including questions about OSS usage and questions about the operating systems used, which include OSS operating systems. For each establishment surveyed, a determination of whether or not it uses OSS is made allowing for the construction of a percentage of all establishments surveyed that use OSS within a given country in a given year. This percentage is multiplied by 100 to change the range to 0-100 (rather than 0 to 1) for ease of interpretation and is used as the outcome variable in the analysis presented in Table 9. The primary independent variable of interest is the number of contributions to OSS, which is measured in 1000's of contributions. The CiTDB does not cover five countries that are in the main analysis (Czech Republic, Estonia, Greece, Latvia, and Slovenia) so the number of observations is lower than in the primary analysis.

The methodologies employed to test this relationship are those discussed above in Section IV.C. Column 1 shows a simple OLS that applies to all countries, independent of the Circulaire 5608. This result, which should not be interpreted causally, shows a positive and significant relationship between the number of contributions to OSS and OSS usage. Column 2 attempts a more causal estimate, uses the control function method, by estimating the results of Equation 1 using the introduction of the Circulaire 5608 as a first-stage shock and the resultant predicted values for the number of OSS contributions as the input into Equation 5. By also controlling for the residuals from the first-stage equation, the coefficient on the fitted value predictions can be interpreted as the impact the regulation has on OSS usage through the increase in contributions to OSS. Columns 3 and 4 can be interpreted together. Column 3 shows a simple estimation of the difference-in-differences equation (Equation 6) where the outcome variable is OSS usage. The coefficient on Treated x Post shows a negative, but not significant impact of the regulation in France. However, Column 4 shows the same specification when adding in the number of OSS contributions (Equation 7). Here, the coefficient on Treated x Post becomes even more negative but the coefficient on new contributors is positive and significant at the 10% level. This offers additional evidence that the increase in OSS usage by establishments in France in the post-period is at least partially due to the increase in the number of contributions to OSS (Angrist and Pischke, 2008).

Interpretation of the lowest estimated coefficient (column 4) indicates that for every 1000 new contributions to OSS that are induced by the Circulaire 5608, the percent of firms that use OSS increases by 0.001 percentage points. Using the most conservative estimate of the number of contributions to OSS per year resulting from the Circulaire 5608 (Table A.1, column 3), which is 599,000, this translates to a (599,000/1,000)*.001 = .599 percentage point increase per year in the number of establishments that start using OSS as a result of the regulation. Using the upper coefficient estimate, that is more precisely measured than the lower bound (Table 9 column 2), but still using the lower bound on the number of contributions to OSS yields an upper estimate of a 5.39 percentage point increase per year in the number of establishments using OSS. To convert this into economic value, consider that in 2014 there where 274,718 businesses in France which means the implementation of the Circulaire 5608 led between 1,645 and 14,807 firms to use OSS that would not have otherwise.[15] Prior research (Nagle, 2019) has shown that the use of OSS can have a positive impact on productivity at firms with an existing ecosystem of complementary assets. In that study, it is shown that roughly 25% of firms gain positive productivity benefits from using OSS (the other 75% have a benefit that is not distinguishable from zero). Therefore, in aggregate, these estimates indicate that the Circulaire 5608 led to a noticeable productivity increase for between 411 and 3702 firms (or between 0.15% and 1.4% of firms) in France in 2014. Further, for the firms that also started contributing to OSS, the benefit they received from using OSS could be up to 100% greater than their free-riding peers (Nagle, 2018).

VI.B. IT Startups

An increase in the availability of OSS and the number of people who understand OSS well enough to contribute to it may also have an impact on the number of startups that are

[15] Data on the number of French businesses comes from the OECD: https://stats.oecd.org/index.aspx?DataSetCode=SSIS_BSC_ISIC4. The percentage estimates calculated in the paper are based on the number of establishments in France, while the data on the number of businesses is the number of enterprises (which can contain multiple establishments. Therefore, these numbers are a lower bound on the number of establishments that adopted OSS as a result of Circulaire 5608. Further, data from 2014 is used as data from 2013 is not available.

founded in the IT space. For example, WhatsApp, a startup that had only 55 employees when Facebook acquired it for $19 billion, stated it relied heavily on OSS since its inception.[16] Therefore, Table 10 uses the number of newly founded IT startups as the outcome variable. This data comes from the Crunchbase database of companies, which includes date of founding as well as industry. Although Crunchbase focuses on companies based in the US, it has reasonable coverage throughout Europe and covers all European countries equally. Therefore, although the number of IT startups in Crunchbase is likely an underestimate of the total number of IT startups in a given country, it is unlikely that this underestimate is greater in one European country than another. The number of first-time contributors to OSS is used as the primary variable of interest and the methodologies employed are discussed above in Section IV.C. Column 1 shows a simple OLS that applies to all countries, independent of the Circulaire 5608. This result, which should not be interpreted causally, shows a positive and significant relationship between the number of new contributors to OSS and new IT startups. Column 2 attempts a more causal estimate, using the control function methodology, by estimating the results of Equation 1 using the introduction of the Circulaire 5608 as a first-stage shock and the resultant predicted values for the number of OSS contributors as the input into Equation 5. By also controlling for the residuals from the first-stage equation, the coefficient on the fitted value predictions can be interpreted as the impact the regulation has on new IT startups through the increase of contributors to OSS. Columns 3 and 4 can be interpreted together. Column 3 shows a simple estimation of the difference-in-differences equation (Equation 6) where the outcome variable is the number of new IT startups. The coefficient on Treated x Post shows a positive and significant impact of the regulation in France. However, Column 4 shows the same specification when adding in the number of new contributors (Equation 7). Here, the coefficient on Treated x Post turns negative, and the coefficient on new contributors is positive and significant at the 1% level. This offers additional evidence that the increase in new IT startups in France in the post-period is at least partially due to the increase in the number of new contributors to OSS (Angrist and Pischke, 2008). Interpretation of the

[16] The website originally located at https://www.whatsapp.com/opensource/ has since been taken down, but has been archived at https://web.archive.org/web/20160323075059/https://www.whatsapp.com/opensource/.

lowest coefficient (column 2) indicates that for every 38 new contributors to OSS that are induced to contribute by the Circulaire 5608, one new IT startup is founded. Using the most conservative estimate of the number of new contributors to OSS per year resulting from the Circulaire 5608 (Table A.4, column 5), which is 883, this translates to 883/38 = 23 new IT startups per year that are founded as a result of the regulation. Doing a similar calculation based on the upper coefficient estimate from Table 10 (column 4), which is .047, but still using the most conservative estimate for the number of new contributors to OSS, leads to an estimate of one new startup for every 21 new contributors yields an estimate of 883/21 = 42 new IT startups per year that are founded as a result of the regulation. In 2012 (the year the regulation is implemented), Crunchbase reports that 229 new IT startups were founded in France. Therefore, the estimates indicate the Circulaire 5608 led to a 9% to 18% increase in the number of IT startups founded per year. This is likely to have a positive impact on economic growth as it has been shown that startups, especially those in technology fields, have important implications for growth (Audretsch, Keilbach, Lehmann, 2006).

VI.C. IT Labor

Given the results in Section V.B that show that the Circulaire 5608 led people who had never contributed to OSS before to start contributing, another logical place to look for domestic economic outcomes is IT-related labor. Prior literature has argued that contributing to OSS allows individuals to learn how to program as part of a team building a large piece of software, rather than just coding on their own (Kogut and Metiu, 2001; Lerner and Tirole, 2002; Lakhani and Wolf, 2005). Further, an increase in the usage of OSS at firms and an increase in the number of IT startups (both discussed above) can also increase the demand for IT Labor. Therefore, Table 11 uses the number of individuals employed in IT related jobs as the outcome variable. This data comes from the Eurostat database and is in 1000's of people.[17] The number of first-time contributors to OSS is used as the primary variable of interest and the methodologies employed are discussed above in Section IV.C. Column 1 shows a simple OLS that applies to all countries, independent of

[17] Data obtained from http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=isoc_sks_itspt&lang=en.

the Circulaire 5608. This result, which should not be interpreted causally, shows a positive and significant relationship between the number of new contributors to OSS and IT labor. Column 2 attempts a more causal estimate, using a control function methodology, by estimating the results of Equation 1 using the introduction of the Circulaire 5608 as a first-stage shock and the resultant predicted values for the number of OSS contributors as the input into Equation 5. By also controlling for the residuals from the first-stage equation, the coefficient on the fitted value predictions can be interpreted as the impact the regulation has on IT labor through the increase of contributors to OSS. Columns 3 and 4 can be interpreted together. Column 3 shows a simple estimation of the difference-in-differences equation (Equation 6) where the outcome variable is the level of IT labor. The coefficient on Treated x Post shows a positive and significant impact of the regulation in France. However, Column 4 shows the same specification when adding in the number of new contributors (Equation 7). Here, the coefficient on Treated x Post is not distinguishable from zero, but the coefficient on new contributors is positive and significant at the 1% level. This offers additional evidence that the increase in IT labor in France in the post-period is at least partially due to the increase in the number of new contributors to OSS (Angrist and Pischke, 2008). Interpreting the lowest of the coefficients (column 4) indicates that 1 additional new contributor to OSS on GitHub leads to 48 new individuals employed in IT labor while the highest of the coefficients (column 2) indicates that 1 additional new contributor to OSS on GitHub leads to 102 new individuals employed in IT labor. Although these numbers may seem very high, it is important to point out that GitHub, although the largest repository of OSS is not the only one.[18] Therefore, while these estimates capture only the tip of the iceberg in terms of new contributors to OSS as result of the Circulaire 5608, the outcome variable captures all IT labor in the population. Further, as shown in sections VI.A and VI.B, the regulation also led to an increase in the use of OSS and the number of IT startups, both of which in turn would require an increase in IT labor, even if those new laborers did not contribute to OSS on Github. At the national economy level, the 883 new contributors to OSS per year (Table A.4, column 5) would lead to an increase

[18] For example, both Linux and Apache, two of the most widely used OSS projects, do not host their code on GitHub. Therefore, it is highly likely that Circulaire 5608 also resulted in new contributors to those projects, but they are not captured in this analysis.

of IT employment by 42,384 to 90,066 people per year. In 2012, the year the law was passed, France had 642,000 people employed in IT jobs indicating that the passage of the law led to an increase of IT labor by between 6.6% and 14% per year. IT labor increases have been shown to have positive effects on firm-level (and in turn national-level) productivity (Tambe and Hitt, 2012).

VI.D. Software patents

Given the apparent increase in the amount of IT labor and IT related startups induced by the Circulaire 5608, it is reasonable to think there might be an increase in the number of software related patents applied for by French residents. However, it is critical to point out that the induced increase in software expertise came with an increased awareness of open source principles. Therefore, it is quite possible that the number of software patents applied for would decrease, relative to other countries, since programmers in France are now more aware of open source methods for creating software. To measure this outcome, we rely on software patents applied for in the United States (rather than Europe). We do so because the rules related to what can be patented make it much easier to obtain a software patent in the United States than in the EU (Guntersdorfer, 2003). Therefore, software patents rarely occur in the EU, but regularly occur in the US. Hence to measure this outcome, data from the US Patent database is obtained via the US Patent and Trademark Office (USPTO) Patent Views database. Because patents can take over a year to be approved, application dates are used rather than grant dates. For each country and year, two relevant statistics are obtained: the total number of patents applied for and the total number of software patents applied for.[19] The latter is the primary outcome variable of interest while the former will be used as an additional control to account for general patent application trends within the country.

As with the analyses above, the number of first-time contributors to OSS is used as the primary variable of interest and the methodologies employed are discussed above in

[19] Patents are considered "software" related if the US Patent Class identifier is between 700 and 799. The 700 – 799 class of patents are those related to "Data Processing: Generic Control Systems or Specific Applications" and are generally understood to be related to software.

Section IV.C. Column 1 shows a simple OLS that applies to all countries, independent of the Circulaire 5608. This result, which should not be interpreted causally, shows a negative and weakly significant relationship between the number of new contributors to OSS and software patent applications. Column 2 attempts a more causal estimate, using a control function methodology, by estimating the results of Equation 1 using the introduction of the Circulaire 5608 as a first-stage shock and the resultant predicted values for the number of OSS contributors as the input into Equation 5. By also controlling for the residuals from the first-stage equation, the coefficient on the fitted value predictions can be interpreted as the impact the regulation has on software patent applications through the increase of contributors to OSS. Columns 3 and 4 can be interpreted together. Column 3 shows a simple estimation of the difference-in-differences equation (Equation 6) where the outcome variable is the number of software patent applications. The coefficient on Treated x Post shows a negative and significant impact of the regulation in France. However, Column 4 shows the same specification when adding in the number of new contributors (Equation 7). Here, the coefficient on Treated x Post becomes less negative, and the coefficient on new contributors is negative and significant at the 10% level. This offers additional evidence that the decrease in software patent applications from France in the post-period is at least partially due to the increase in the number of new contributors to OSS (Angrist and Pischke. 2008). Interpretation of the lowest coefficient (column 4) indicates that for every 62 new contributors to OSS that are induced to contribute by the Circulaire 5608, one fewer software patent is filed. Using the most conservative estimate of the number of new contributors to OSS per year resulting from the Circulaire 5608 (Table A.4, column 5), which is 883, this translates to 883/62 = 14 fewer software patents are applied for as a result of the regulation. Doing a similar calculation based on the upper coefficient estimate from Table 12 (column 2), which is -0.047, but still using the most conservative estimate for the number of new contributors to OSS, leads to an estimate of one fewer software patent application for every 21 new contributors yields an estimate of 883/21 = 42 fewer software patent applications per year as a result of the regulation. In 2012 (the year the regulation is implemented), the USPTO reports that 266 software patents were applied for from France. Therefore, the estimates indicate the Circulaire 5608 led to a 5% to 16% decrease in the number of software patents applied for per year.

Whether or not this decrease in software patenting is a good thing for France is debatable. At face value, patents are a proxy for innovation and R&D, which are generally considered important for productivity and growth so a decrease in patenting activity would be bad. However, arguments have been made that patents in general, and in the software space in particular due to the fast-moving nature of the field, reduce the ability for follow-on innovation thereby retarding innovation and growth (Bessen and Maskin, 2009; Hall and MacGarvie, 2010; Galasso and Schabnkerman, 2014; Gambardella and von Hippel, 2017). Therefore, it is quite possible that this reduction in software patenting activity will lead to a positive impact on France's future growth in the industry.

VII. Conclusion

This study examines the impact of the French regulation Circulaire 5608, which required government agencies to favor OSS in the technology procurement process. It shows that the passage of the regulation led to an increase of 599,000 OSS contributions per year from individuals in France, which created a social value of nearly $20 million per year. A placebo test using a similar law passed in Italy that was never enforced shows this effect was indeed the result of the law rather than any underlying trends that led to the passage of the law. The study also shows this increase in contributions led to benefits for France that increased its national productivity and competitiveness by increasing the number of firms using OSS, the number of IT startups, and the amount of IT labor, and decreasing the number of software related patents. Given that the primary reason France implemented Circulaire 5608 was for cost savings, this study identifies a cost-effective policy lever countries can use to both create global social value and increase their own national competitiveness.

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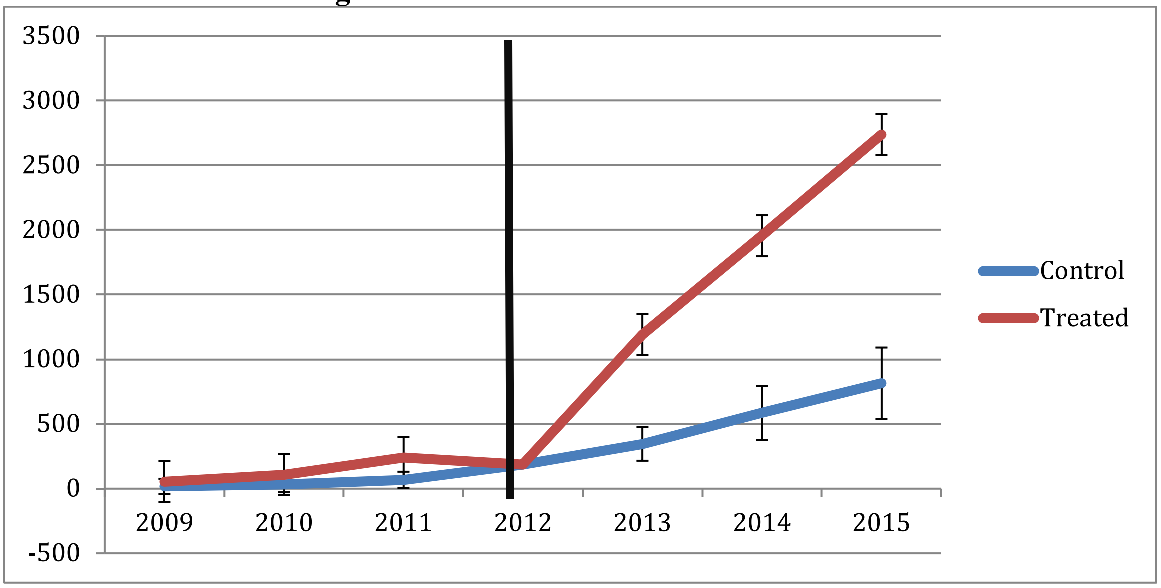
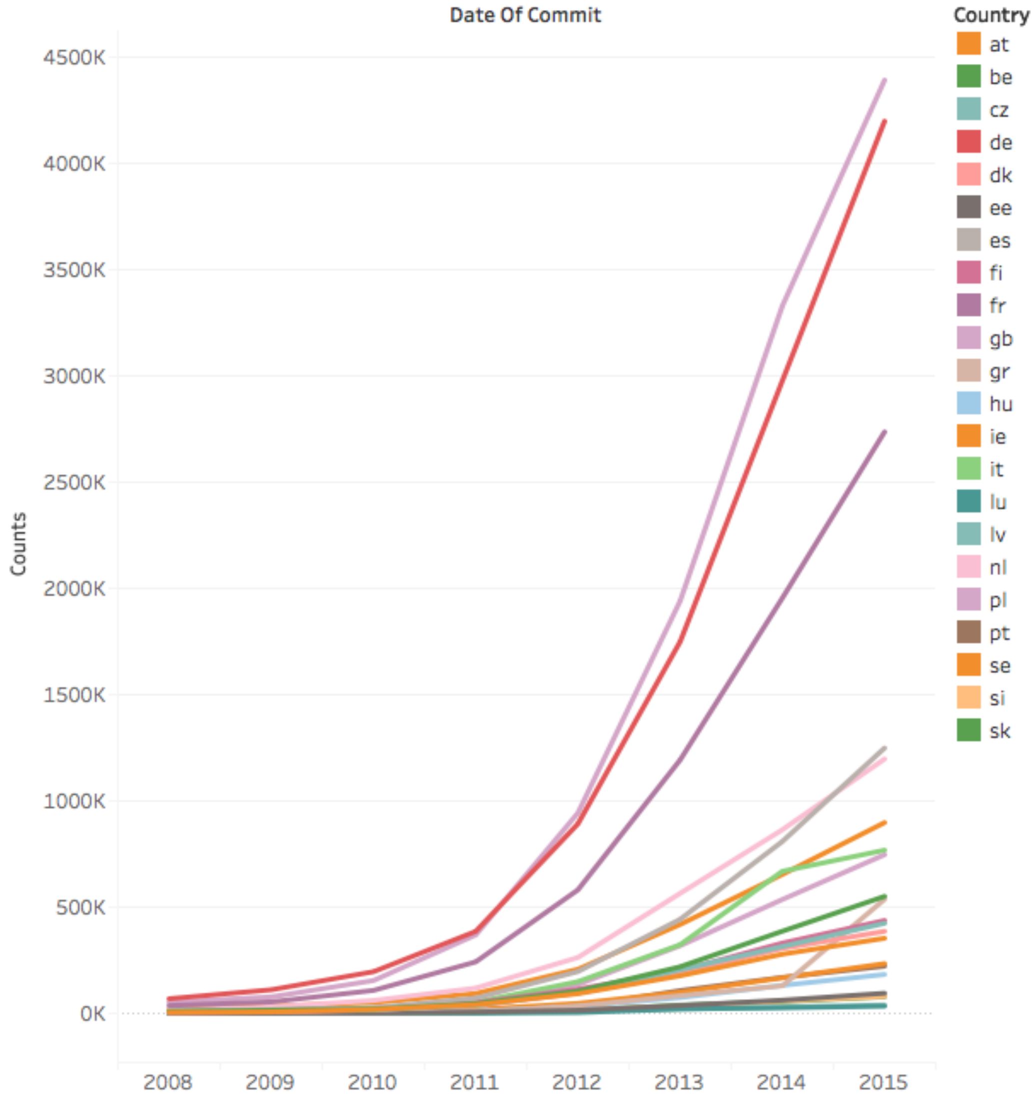
Figures

Figure 1: OSS Contributions on GitHub



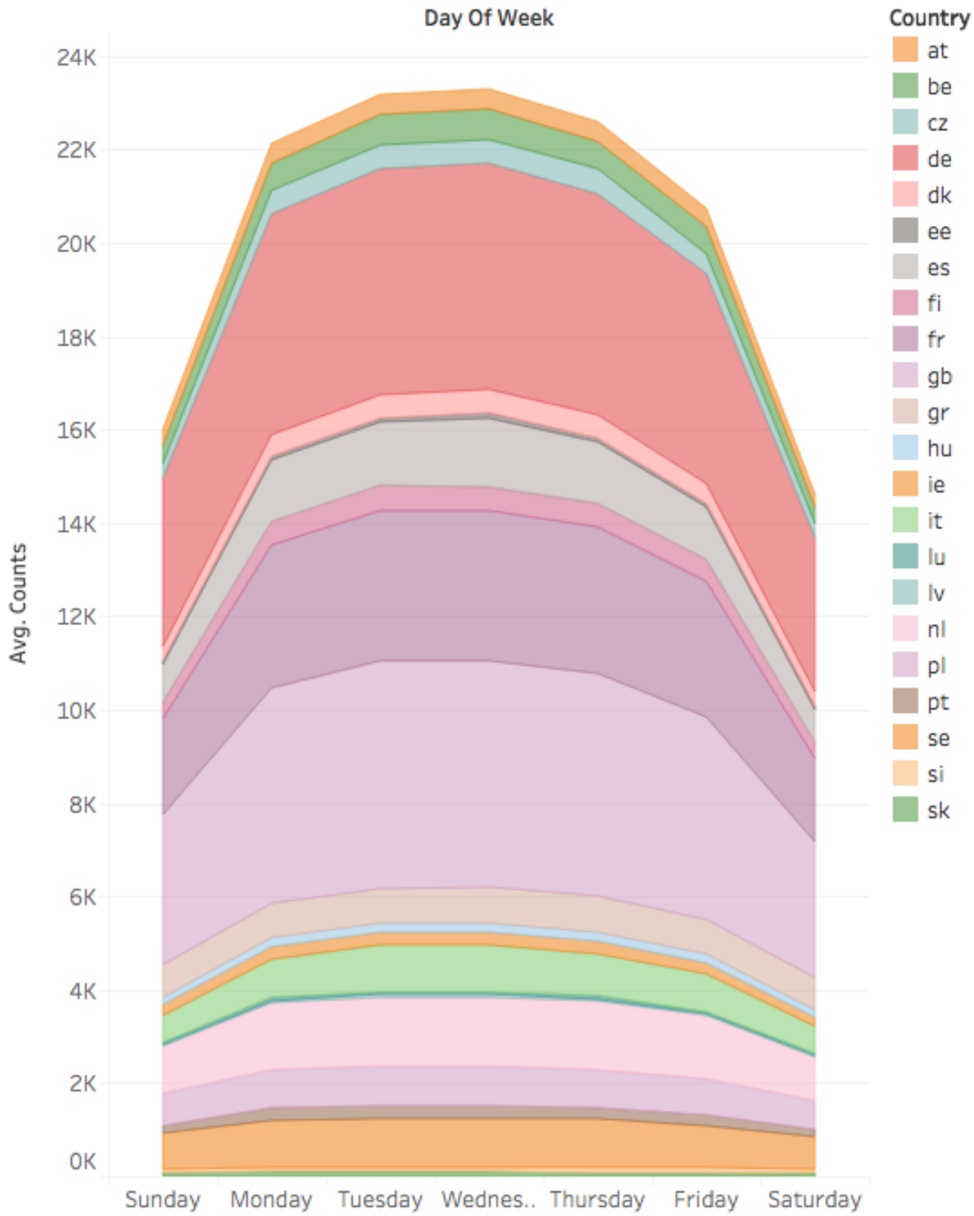
The treated observation is the country of France. Control observations are the 20 other European/OECD countries. The vertical axis represents the number of OSS contributions to GitHub measured in 1000's. Circulaire 5608 was passed into law in September 2012, represented by the vertical line.

Figure 2: GitHub OSS Commits by Country



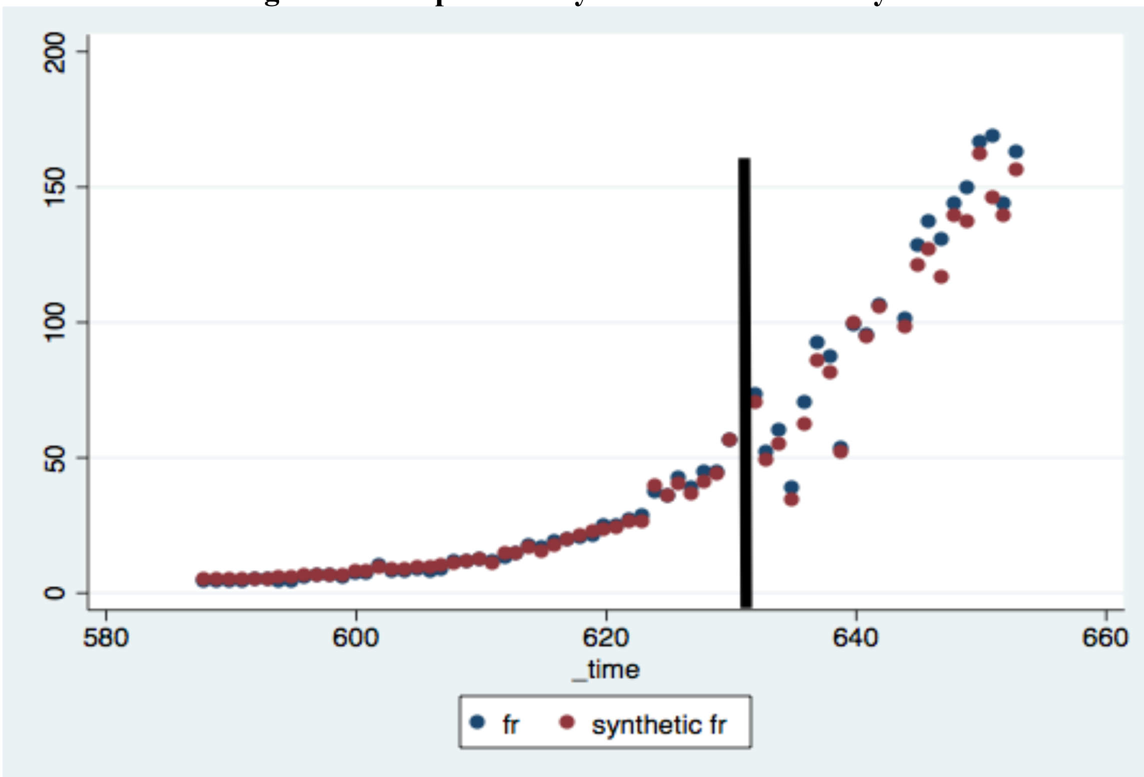
The vertical axis shows the yearly number of OSS commits to GitHub by country. France, the primary country of interest is represented in purple and is consistently the third highest contributor.

Figure 3: Average Number of Contributions Per Day



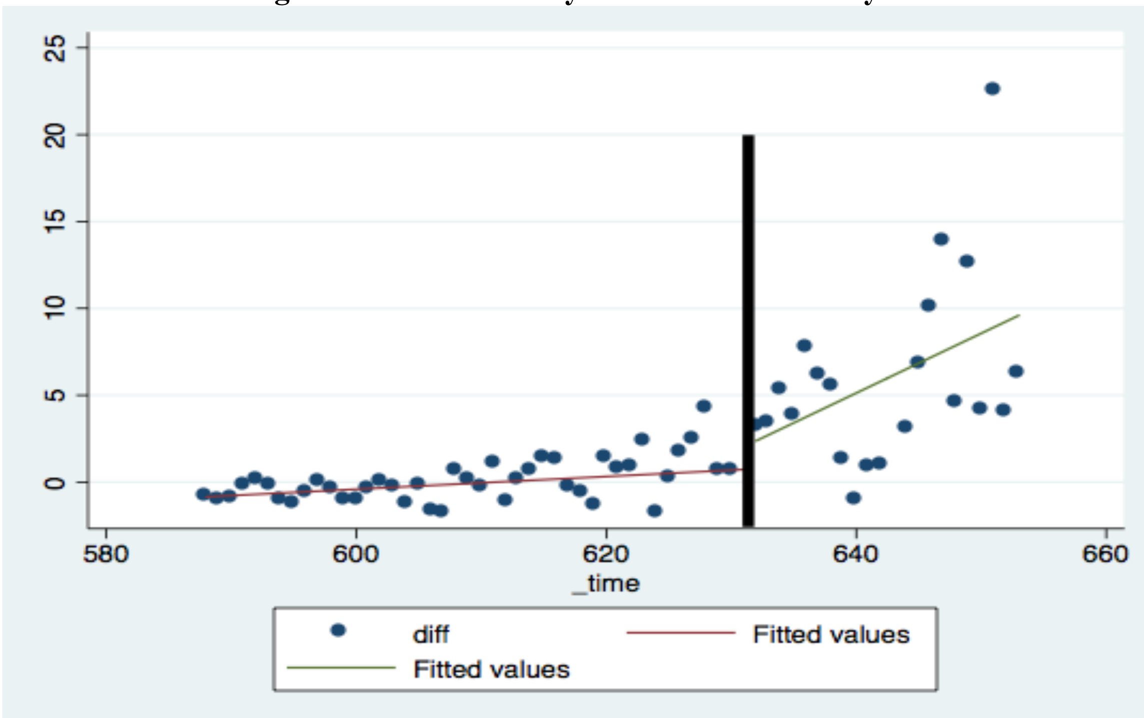
The vertical axis shows the average number of OSS commits to GitHub by country by day of the week.

Figure 4: Comparative Synthetic Control Analysis



The vertical axis shows the monthly number of OSS commits to GitHub (in 1000's). France is represented by the blue dots and the synthetic version of France, constructed using the method from Abadie, Diamond, and Hainmueller (2010) based on all available control variables including OSS commits in the pre-period, is in red. The vertical line represents the date of the introduction of Circulaire 5608 in September 2012. Prior to that point, the levels of contribution are nearly identical between France and synthetic France. After the law is introduced, France shows consistently more contributions than synthetic France.

Figure 5: Differenced Synthetic Control Analysis



The vertical access shows the monthly number of OSS commits to GitHub (in 1000's). The synthetic control construction is the same as in Figure 4, but this figure shows the difference in contribution level by subtracting the contributions of synthetic France from those of actual France. The vertical line represents the date of the introduction of Circulaire 5608 in September 2012. Prior to that point, the difference in level of contribution hovers around zero and the trendline is fairly flat.. After the law is introduced, France shows consistently more contributions than synthetic France and the plotted difference increases steadily over time.

Tables

Table 1: EU and OECD Member Countries

Austria (AT)	**Italy (IT)**
Belgium (BE)	**Latvia (LV)**
Czech Republic (CZ)	**Luxembourg (LU)**
Denmark (DK)	**Netherlands (NL)**
Estonia (EE)	**Poland (PL)**
Finland (FI)	**Portugal (PT)**
France (FR)	**Slovakia (SK)**
Germany (DE)	**Solvenia (SI)**
Greece (GR/EL)	**Spain (ES)**
Hungary (HU)	**Sweden (SE)**
Ireland (IE)	**United Kingdom (UK/GB)**

Table 2: Summary Statistics

Variable	Time Period	Obs	Mean	Std. Dev.	Min	Max
OSS Contributions (in 1000's)	Monthly	2,054	31.634	66.913	.001	444.451
OSS Contributions (in 1000's)	Yearly	176	369.183	736.851	.107	4394.574
Number of New Contributors	Monthly	2,054	167.478	254.264	1	1701
Number of New Contributors	Yearly	176	1909.824	2956.54	8	15088
Avg. Number of Contributors per day	Monthly	2,054	226.895	454.216	.032	3329.964
Avg. Number of Contributors per day	Yearly	176	220.454	422.114	.167	2593.126
OSS Contributions during work hours (in 1000's)	Monthly	2,054	12.474	27.105	0	195.454
OSS Contributions during work hours (in 1000's)	Yearly	176	145.572	294.375	52	1855.912
OSS Contributions during non-work hours (in 1000's)	Monthly	2,054	18.365	38.984	1	279.936
OSS Contributions during non-work hours (in 1000's)	Yearly	176	214.322	422.209	55	2515.875
Population	Yearly	176	$2.14x10^7$	$2.47x10^7$	497783	$8.27x10^7$
GDP (Millions of USD)	Yearly	176	796289.8	986531.2	27388.71	4041192
GDP per Capita (USD)	Yearly	176	38350.34	15694.07	16886.64	105767.8
GDP Growth (% change)	Quarterly	704	.284	1.386	-6.817	21.366
Government Expenditure (% of GDP)	Yearly	176	20.852	2.961	12.549	27.935
Population Internet Availability (% of population with access)	Yearly	176	77.222	12.073	42.4	97.49
Unemployment (%)	Yearly	154	9.881	4.915	3.436	27.486
% with less than upper secondary education	Yearly	154	22.675	13.468	6.810	70.095
% with upper secondary education	Yearly	154	47.514	14.174	15.238	75.858
% with tertiary education	Yearly	154	29.811	7.797	14.511	45.936
Household Internet Availability (% of households with home access)	Yearly	154	75.768	12.303	38.065	95.966

This table presents the summary statistics for the 22 countries in the sample. The contribution variables are presented at both the monthly and yearly level. The time period is January 2009 to September 2016, which is 93 months or 8 years (with the final year only consisting of 9 months). The final five control variables have a reduced number of observations because data for 2016 was not yet available.

Table 3: Impact of Circulaire 5608 on Monthly OSS Contributions from France

	(1)	(2)	(3)	(4)	(5)
	OSS Contributions				
Treated	14.584***	-51.927**	-42.186**	-46.190**	-33.557
	(2.125)	(20.533)	(20.049)	(18.854)	(39.444)
Post	46.937***	36.923***	35.641***	68.018**	-202.324***
	(15.457)	(10.704)	(12.461)	(25.198)	(27.168)
Treated x Post	97.226***	72.000***	49.659***	57.111***	55.692***
	(15.457)	(14.486)	(13.463)	(11.550)	(17.652)
Constant	5.963**	-2.181	138.287	129.912	97.727**
	(2.125)	(12.360)	(121.054)	(115.332)	(45.098)
Model	OLS	OLS	OLS	OLS	RE
Control Level	None	Low	High	High	Low
Year/Month Time Fixed Effect	No	No	No	Yes	Yes
N	1961	1961	1748	1748	1961
Num. of Clusters	21	21	21	21	21
R^2	0.207	0.623	0.646	0.681	0.723

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of OSS contributions on GitHub in 1000's per month. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, GDP growth per quarter, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table 4: Impact of Circulaire 5608 on Monthly Work vs. Non-Work OSS Contributions

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OSS Contributions During Work Hours				OSS Contributions During Non-Work Hours			
Treated	6.196***	-20.445**	-16.337*	-17.935**	8.388***	-29.946**	-24.720**	-26.978**
	(0.854)	(8.398)	(8.102)	(7.635)	(1.272)	(11.531)	(11.380)	(10.699)
Post	18.198***	14.058***	14.035**	28.502**	27.222***	21.615***	20.497***	39.498**
	(6.183)	(4.204)	(5.011)	(10.207)	(8.829)	(6.196)	(7.087)	(14.932)
Treated x Post	41.935***	32.394***	21.481***	24.335***	52.692***	37.774***	27.423***	31.654***
	(6.183)	(5.699)	(5.320)	(4.573)	(8.829)	(8.400)	(7.775)	(6.703)
Constant	2.381**	-4.921	58.925	56.194	3.582**	1.934	74.682	70.327
	(0.854)	(4.897)	(52.017)	(49.782)	(1.272)	(7.669)	(65.806)	(62.915)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Control Level	None	Low	High	High	None	Low	High	High
Year/Month Time Fixed Effect	No	No	No	Yes	No	No	No	Yes
Num. of Clusters	21	21	21	21	21	21	21	21
N	1961	1961	1748	1748	1961	1961	1748	1748
R^2	0.205	0.598	0.617	0.657	0.196	0.609	0.645	0.686

***p<.01, **p<.05, *p<.1. The outcome variable for columns 1-4 is the number of OSS contributions on GitHub in 1000's per month that are made during Monday-Friday, 8am-6pm local time. The outcome variable for columns 5-8 is the number of OSS contributions on GitHub in 1000's per month that are made during all other times. All models use robust standard errors clustered at the country level and are ordinary least squares. The "low" level of controls includes population, GDP, GDP per Capita, GDP growth per quarter, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table 5: Impact of Circulaire 5608 on Average Number of Daily OSS Contributors by Month

	(1)	(2)	(3)	(4)	(5)
	Number of Daily Contributors				
Treated	125.272***	-360.993**	-289.665**	-319.328**	-228.474
	(17.986)	(140.946)	(138.779)	(130.152)	(284.382)
Post	314.498***	241.488***	248.825***	462.183**	-1435.632***
	(103.810)	(71.307)	(84.984)	(167.725)	(191.516)
Treated x Post	718.890***	561.202***	401.903***	445.251***	418.746***
	(103.810)	(95.311)	(90.309)	(79.838)	(124.296)
Constant	51.736***	-148.056*	1036.463	1011.086	728.689**
	(17.986)	(79.921)	(870.686)	(838.917)	(369.325)
Model	OLS	OLS	OLS	OLS	OLS RE
Control Level	None	Low	High	High	Low
Year/Month Time Fixed Effect	No	No	No	Yes	Yes
N	1961	1961	1748	1748	1961
Num. of Clusters	21	21	21	21	21
R^2	0.220	0.652	0.675	0.704	0.764

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the average daily number of OSS contributors on GitHub by month. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, GDP growth per quarter, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table 6: Impact of Circulaire 5608 on New OSS Contributors by Month

	(1)	(2)	(3)	(4)	(5)
	Number of New Contributors				
Treated	248.437***	-149.475*	-151.315*	-171.943**	-85.376
	(40.281)	(76.960)	(83.150)	(78.924)	(160.231)
Post	56.063***	17.146	28.719	52.266	-299.003***
	(16.905)	(10.038)	(18.884)	(43.450)	(100.049)
Treated x Post	140.908***	103.384***	244.912***	219.260***	67.382***
	(16.905)	(12.650)	(17.288)	(24.378)	(22.926)
Constant	125.126***	-311.087**	303.428	445.885	15.711
	(40.281)	(112.136)	(463.059)	(496.865)	(285.832)
Model	OLS	OLS	OLS	OLS	OLS RE
Standard Error	Cluster	Cluster	Cluster	Cluster	Cluster
Control Level	None	Low	High	High	Low
Year/Month Time Fixed Effect	No	No	No	Yes	Yes
N	1961	1961	1748	1748	1961
Num. of Clusters	21	21	21	21	21
R^2	0.087	0.643	0.793	0.832	0.838

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of first-time OSS contributors on GitHub by month. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The “low” level of controls includes population, GDP, GDP per Capita, GDP growth per quarter, government expenditure, and percentage of the population with Internet availability. The “high” level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table 7: Impact of CAD Article 68 on Monthly OSS Contributions from Italy

	(1)	(2)	(3)	(4)	(5)
	OSS Contributions				
Treated	-0.977	-52.801***	-45.166**	-46.315**	-47.135
	(2.125)	(17.721)	(19.766)	(19.386)	(39.542)
Post	46.937***	37.129***	35.573***	67.418**	-226.123***
	(15.457)	(10.712)	(12.411)	(25.249)	(19.300)
Treated x Post	-0.573	-2.128	4.421	8.676	-5.751
	(15.457)	(11.864)	(7.191)	(6.374)	(10.143)
Constant	5.963**	-2.327	139.696	131.133	100.175**
	(2.125)	(12.109)	(121.156)	(115.633)	(46.423)
Model	OLS	OLS	OLS	OLS	RE
Control Level	None	Low	High	High	Low
Year/Month Time Fixed Effect	No	No	No	Yes	Yes
N	1961	1961	1748	1748	1961
Num. of Clusters	21	21	21	21	21
R^2	0.133	0.598	0.632	0.666	0.698

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of OSS contributions on GitHub in 1000's per year. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, GDP growth per quarter, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.

Table 8: Summary Statistics for Economic Outcomes

Variable	Obs	Mean	Std. Dev.	Min	Max
Establishments using OSS (%)	118	.071	.068	.004	.313
Num. of ICT companies founded	176	91.851	146.495	2	844
IT Employment (in 1000's)	176	308.834	389.660	9.8	1608.2
Total Num. of US patents applied for	176	1236.767	2454.669	1	13879
Num. of US software patents applied for	176	72.580	184.644	0	1159

This table presents the summary statistics for the 22 countries and 8 years in the sample with the exception of the percentage of establishments using OSS, for which data was only available for 17 countries and 7 years.

Table 9: Impact of Circulaire 5608 on Establishment Usage of OSS

	(1)	(2)	(3)	(4)
	Percent of Establishments Using OSS			
Treated			-4.484**	-4.240***
			(1.591)	(1.340)
Post			4.503***	3.947***
			(1.139)	(1.300)
Treated x Post			-0.434	-1.085
			(1.155)	(0.986)
OSS Contributions (1000's)	0.003***			0.001*
	(0.001)			(0.001)
Fitted values		0.009***		
		(0.002)		
Residuals		0.001*		
		(0.001)		
Constant	24.653***	22.156***	-5.359	-9.691
	(7.530)	(7.412)	(17.438)	(15.288)
Model	OLS	OLS w/ Predicted Values and Residuals	OLS	OLS
Control Level	High	High	High	High
N	110	110	110	110
Num. of Clusters	16	16	16	16
R^2	0.756	0.797	0.803	0.808

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the percentage of establishments within the country that use OSS. All models use robust standard errors clustered at the country level. All models 1-4 are ordinary least squares. Model 2 uses a first stage OLS to calculate the impact of the regulatory shock on the number of contributions to OSS and then uses the fitted values and residuals from this estimate to estimate the impact of the regulation on the percentage of establishments using OSS. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.

Table 10: Impact of Circulaire 5608 on IT Startup Founding

	(1)	(2)	(3)	(4)
	Number of IT Startups Founded			
Treated			-126.915	-40.426
			(89.912)	(43.596)
Post			-8.705	-24.754*
			(18.083)	(13.770)
Treated x Post			50.990***	-88.582***
			(16.913)	(20.520)
Num. New OSS	0.046***			0.047***
Contributors	(0.007)			(0.005)
Fitted values		0.026*		
		(0.014)		
Residuals		0.047***		
		(0.006)		
Constant	182.126	176.511	688.756	516.009*
	(110.882)	(112.391)	(471.476)	(281.502)
Model	OLS	OLS w/ Predicted Values and Residuals	OLS	OLS
Control Level	High	High	High	High
N	146	146	146	146
Num. of Clusters	21	21	21	21
R^2	0.864	0.866	0.716	0.878

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of IT startups founded in a given year within the country. All models use robust standard errors clustered at the country level. All models 1-4 are ordinary least squares. Model 2 uses a first stage OLS to calculate the impact of the regulatory shock on the number of new contributors to OSS and then uses the fitted values and residuals from this estimate to estimate the impact of the regulation on the number of new IT startups founded. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.

Table 11: Impact of Circulaire 5608 on IT Labor

	(1)	(2)	(3)	(4)
	1000's of Individuals Employed in IT Jobs			
Treated			-394.921***	-306.946***
			(124.081)	(94.367)
Post			11.953	-4.372
			(25.295)	(16.306)
Treated x Post			159.518***	17.549
			(28.909)	(57.498)
Num. New OSS Contributors	0.052***			0.048***
	(0.006)			(0.010)
Fitted values		0.102***		
		(0.017)		
Residuals		0.048***		
		(0.007)		
Constant	228.005	242.183	518.652	342.938
	(225.135)	(224.498)	(525.384)	(313.409)
Model	OLS	OLS w/ Predicted Values and Residuals	OLS	OLS
Control Level	High	High	High	High
N	146	146	146	146
Num. of Clusters	21	21	21	21
R^2	0.939	0.941	0.928	0.956

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of individuals employed in IT related jobs in 1000's in a given year within the country. All models use robust standard errors clustered at the country level. All models 1-4 are ordinary least squares. Model 2 uses a first stage OLS to calculate the impact of the regulatory shock on the number of new contributors to OSS and then uses the fitted values and residuals from this estimate to estimate the impact of the regulation on the number of individuals employed in IT related jobs. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.

Table 12: Impact of Circulaire 5608 on Software Patents

	(1)	(2)	(3)	(4)
	Number of Software Patents Applied For in US			
Treated			86.123**	53.495
			(39.382)	(45.240)
Post			-27.383	-27.827
			(16.970)	(17.252)
Treated x Post			-124.621***	-87.383**
			(27.697)	(36.268)
Num. New OSS Contributors	-0.018* (0.010)			-0.016* (0.009)
Fitted values		-0.047**		
		(0.021)		
Residuals		-0.016*		
		(0.009)		
Constant	9.279	-24.863	200.166	231.492
	(88.291)	(90.644)	(180.784)	(204.721)
Model	OLS	OLS w/ Predicted Values and Residuals	OLS	OLS
Control Level	High	High	High	High
N	146	146	146	146
Num. of Clusters	21	21	21	21
R^2	0.904	0.906	0.898	0.909

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of US software patents applied for by an inventor in a given year within the country. All models use robust standard errors clustered at the country level. All models 1-4 are ordinary least squares. Model 2 uses a first stage OLS to calculate the impact of the regulatory shock on the number of new contributors to OSS and then uses the fitted values and residuals from this estimate to estimate the impact of the regulation on number of US software patents applied for. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.

Appendix

Table A.1: Impact of Circulaire 5608 on Yearly OSS Contributions from France

	(1)	(2)	(3)	(4)	(5)
	OSS Contributions				
Treated	175.079***	-619.591**	-511.749*	-562.509**	-412.561
	(25.700)	(247.966)	(249.948)	(233.491)	(437.019)
Post	528.277***	416.974***	425.087**	755.627**	344.554***
	(177.501)	(126.825)	(154.872)	(289.437)	(123.986)
Treated x Post	1160.505***	854.876***	599.000***	689.663***	613.103***
	(177.501)	(172.348)	(166.634)	(141.386)	(204.918)
Constant	71.477**	-25.326	1641.305	1566.489	959.059**
	(25.700)	(148.563)	(1518.560)	(1459.813)	(464.358)
Model	OLS	OLS	OLS	OLS	OLS RE
Control Level	None	Low	Medium	Medium	Low
Year Time Fixed Effect	No	No	No	Yes	Yes
N	168	168	146	146	168
Num. of Clusters	21	21	21	21	21
R^2	0.225	0.705	0.661	0.690	0.767

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of OSS contributions on GitHub in 1000's per year. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table A.2: Impact of Circulaire 5608 on Yearly Work vs. Non-Work OSS Contributions from France

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	OSS Contributions During Work Hours				OSS Contributions During Non-Work Hours			
Treated	74.376***	-243.838**	-198.649*	-219.230**	100.702***	-357.348**	-299.375**	-327.759**
	(10.325)	(101.583)	(101.044)	(94.712)	(15.384)	(139.131)	(141.830)	(132.368)
Post	204.777***	158.535***	167.381**	299.988**	306.303***	244.195***	244.606**	431.097**
	(70.988)	(49.713)	(62.259)	(116.362)	(101.362)	(73.471)	(88.161)	(164.352)
Treated x Post	499.649***	384.003***	259.321***	294.039***	629.694***	448.998***	330.647***	382.080***
	(70.988)	(67.844)	(65.747)	(55.869)	(101.362)	(99.878)	(96.343)	(82.190)
Constant	28.538**	-58.046	703.084	680.238	42.939**	23.226	885.819	846.074
	(10.325)	(59.451)	(652.611)	(630.548)	(15.384)	(91.847)	(826.335)	(795.810)
Model	OLS	OLS	OLS	OLS	OLS	OLS	OLS	OLS
Control Level	None	Low	High	High	None	Low	High	High
Year Time Fixed Effect	No	No	No	Yes	No	No	No	Yes
N	168	168	146	146	168	168	146	146
Num. of Clusters	21	21	21	21	21	21	21	21
R^2	0.230	0.696	0.647	0.675	0.220	0.712	0.677	0.705

***p<.01, **p<.05, *p<.1. The outcome variable for columns 1-4 is the number of OSS contributions on GitHub in 1000's per year that are made during Monday-Friday, 8am-6pm local time. The outcome variable for columns 5-8 is the number of OSS contributions on GitHub in 1000's per year that are made during all other times. All models use robust standard errors clustered at the country level and are ordinary least squares. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household.The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table A.3: Impact of Circulaire 5608 on Average Number of Daily OSS Contributors by Year

	(1)	(2)	(3)	(4)	(5)
	Number of Daily Contributors				
Treated	125.375***	-358.230**	-292.991*	-323.663**	-237.846
	(18.133)	(141.873)	(144.051)	(134.462)	(258.872)
Post	293.916***	226.011***	247.304**	437.013**	162.832***
	(99.053)	(70.082)	(87.978)	(163.272)	(61.835)
Treated x Post	712.659***	553.339***	403.790***	447.549***	389.719***
	(99.053)	(94.367)	(93.018)	(81.495)	(119.250)
Constant	51.705***	-145.203*	1028.510	1018.682	563.511*
	(18.133)	(80.314)	(909.476)	(884.105)	(303.756)
Model	OLS	OLS	OLS	OLS	OLS RE
Control Level	None	Low	High	High	Low
Year Time Fixed Effect	No	No	No	Yes	Yes
N	168	168	146	146	168
Num. of Clusters	21	21	21	21	21
R^2	0.234	0.720	0.684	0.708	0.790

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the average daily number of OSS contributors on GitHub by year. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table A.4: Impact of Circulaire 5608 on New OSS Contributors by Year

	(1)	(2)	(3)	(4)	(5)
	Number of New Contributors				
Treated	2989.050***	-1700.144*	-1831.047*	-2069.853*	-1708.299
	(486.023)	(919.140)	(1044.619)	(994.302)	(1059.746)
Post	467.663***	70.247	339.775	1215.634*	-1052.747***
	(149.949)	(103.853)	(235.083)	(668.581)	(341.240)
Treated x Post	1468.087***	1042.614***	2954.838***	2653.730***	883.836***
	(149.949)	(160.511)	(211.044)	(298.298)	(134.543)
Constant	1493.700***	-3754.401**	3657.201	5381.061	-3873.857***
	(486.023)	(1391.083)	(5805.929)	(6258.230)	(1248.133)
Model	OLS	OLS	OLS	OLS	OLS RE
Control Level	None	Low	High	High	Low
Year/ Time Fixed Effect	No	No	No	Yes	Yes
N	168	168	146	146	168
Num. of Clusters	21	21	21	21	21
R^2	0.080	0.629	0.818	0.847	0.806

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of first-time OSS contributors on GitHub by year. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is France and the post-period starts after the passage of Circulaire 5608 in September 2012.

Table A.5: Impact of CAD Article 68 on Yearly OSS Contributions from Italy

	(1)	(2)	(3)	(4)	(5)
	OSS Contributions				
Treated	-11.648	-634.357***	-544.371**	-558.922**	-556.280
	(25.700)	(212.469)	(245.960)	(239.202)	(430.140)
Post	528.277***	419.663***	424.468**	748.189**	344.599***
	(177.501)	(126.930)	(154.180)	(289.504)	(121.608)
Treated x Post	-10.418	-42.466	57.628	109.899	-70.406
	(177.501)	(142.276)	(88.849)	(78.490)	(117.400)
Constant	71.477**	-26.809	1659.742	1581.885	986.581**
	(25.700)	(145.301)	(1519.019)	(1462.886)	(476.857)
Model	OLS	OLS	OLS	OLS	RE
Control Level	None	Low	High	High	Low
Year/Month Time Fixed Effect	No	No	No	Yes	Yes
N	168	168	147.000	147.000	168
Num. of Clusters	21	21	21	21	21
R^2	0.140	0.678	0.648	0.677	0.763

***p<.01, **p<.05, *p<.1. The outcome variable for all columns is the number of OSS contributions on GitHub in 1000's per year. All models use robust standard errors clustered at the country level. Models 1-4 are ordinary least squares and model 5 uses a country-level random-effect. The "low" level of controls includes population, GDP, GDP per Capita, government expenditure, and percentage of the population with Internet availability. The "high" level of controls includes all of the low level controls as well as unemployment percentage, education level, and percentage of the population with Internet available at their household. The treated observation is Italy and the post-period starts after the passage of CAD Article 68 in August 2012.