

# The relationship between copyright software protection and piracy: Evidence from europe

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**Abstract** This paper provides an empirical analysis of the relationship between software protection and national piracy rates across 23 European countries over a period of three years (1994, 1997, and 2000). The analysis not only constructs a new index of copyright software protection but remedies previous econometric and methodological shortcomings by applying a macro level panel data technique. Results indicate that copyright software protection and income are the most determinant factors of software piracy. In addition, the model predicts an inverted U relationship between piracy and per capita income. Moreover, the above findings are robust to the inclusion of other descriptors suggested by the empirical literature on piracy.

**Keywords** Piracy · Copyright · Intellectual property rights · Enforcement · Panel data · Software protection

**JEL Classification** O34 · L86

In legal terms, intellectual property covers three distinct sets of rights: copyrights, patents, and trademarks.<sup>1</sup> However, economics differentiates between copyright and patent on the one hand and trademark on the other based on the following rationale. Copyright refers to two types of commodity—information or intellectual property goods<sup>2</sup>—having certain characteristics. Information goods have two important public goods characteristics. First, their consumption is inherently non-rival. That is, the use that one person makes of a piece of information or intellectual property goods does not decrease the possibility of use by others. Second, information or intellectual property goods may be non-excludable in the sense that the producer of intellectual property goods is often unable to exclude non-payers from consuming goods without due authorization. Intellectual property law responds to this non-excludability

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<sup>1</sup> See Besen and Raskind (1991) for an introduction to the economics of intellectual property rights.

<sup>2</sup> Varian (1998) defines an information good as anything that can be digitized. Books, records, news, telephone conversations, magazines, and software fall into this category.

problem by giving producers certain exclusive rights that exclude non-payers from certain uses of their intellectual property goods.<sup>3</sup> Thus, the producers are able to reap the benefits from the production of information goods for a certain period of time. However, the rights holder can charge a price above the marginal cost and this together with the non-rivality feature of information goods creates deadweight loss. Therefore, an adequate intellectual property system must ensure a fair balance between these two conflicting objectives.

As regards intellectual property protection, one serious concern for copyright holders is piracy; that is, the unauthorized use of copyrighted goods. When a legal copyright exists, those who wish to gain access to the original copyrighted work must pay the copyright holder the access price. If an individual obtains access without paying a price, that person is said to have incurred an act of piracy. Even though piracy occurs for all types of intellectual property and can take many forms depending on the access type and intellectual property mechanism (Watt, 2001), one of the most worrying areas nowadays is certainly the piracy of business software applications. Whereas piracy and counterfeiting in general account for 5 percent and 7 percent, respectively, of world trade,<sup>4</sup> in 2002, the piracy rates for PC business software in Western and Eastern Europe were 35 percent and 71 percent, respectively, which translated into a \$3.2 and \$1.1 billion loss in revenue dollars (IPRC, 2003).<sup>5</sup>

The emergence of digital technologies poses a new threat to software publishers' revenues because these technologies provide the opportunity for copyright violation to a wide spectrum of users (Gallegos, 1999; Gopal and Sanders, 2000; Moorehouse, 2001). The response from copyright holders and their copyright collectives has been to call for a wider scope of copyright legislation and increased enforcement. Therefore, a better understanding of pirate behaviors may be important for the formulation of appropriate copyright policies to curb the software piracy problem.

Nevertheless, quantitative research that focuses on or even highlights the effect of legal variables on piracy is rare. Of the three empirical studies that include international country membership as a proxy variable for intellectual property rights (IPR) protection and test this hypothesis using ordinary least squares (OLS), only two (Papadopoulos, 2003; Van Kranenburg, and Hogenbirk, 2005) find a statistically significant effect. In addition, the validity and usefulness of the majority of cross-country studies may be questioned. First, in the empirical literature on piracy, there are no clear theoretical arguments for the impact of the strength of software protection on piracy. In this context, incorporating other strands of the economic literature—for instance, that on criminal behavior and illegal copying—may help clarify why legal protection can be expected to influence national piracy rates. Second, these studies, particularly those using a legal framework, are either subject to the multicollinearity problem or use rough proxies for the strength of a country's IPR.<sup>6</sup> Moreover, even though several scholars corroborate the importance of enforcement issues in any measure of the

<sup>3</sup> Economic theory suggests two alternative solutions to this problem: (1) subsidize the production of creative works and (2) reward the authors of original works (see Shavell and Van Ypersele, 2001).

<sup>4</sup> See COM(98)569.

<sup>5</sup> Theoretically, there are several reasons why piracy will not be damaging to the copyright holders. As piracy enlarges the installed base of users (legal or illegal), it creates network effects that increase the consumers' willingness to pay for the software, thereby potentially increasing the producers' profits (Conner and Rumelt, 1991; Takeyama, 1994; Shy and Thisse, 1999). Another wave of papers assumes that copies can be made from originals so that producers of information goods can indirectly appropriate part of the consumer surplus (e.g., Johnson, 1985; Liebowitz, 1985; Besen and Kirby, 1989; Varian, 2000). Even in the absence of network effects, piracy may be profitable because of indirect appropriation.

<sup>6</sup> Regarding the relevance of this kind of variable, Maskus (2000b) argues that "international membership can be at best only a crude indicator of the strength of intellectual property systems."

strength of intellectual property systems (e.g., Ostergard, 2000), many studies neglect the enforcement aspects of IPR. Third, most of these empirical contributions are confined to a cross-sectional estimation method and are therefore unable to account for changes over time and unobserved individual heterogeneity. If these individual effects are correlated with the explanatory variables included in the model, the estimates will be biased and the true explanatory power of the included variables unknown. An alternative solution to the problem of piracy studies at a macro level is a panel data technique, but this technique has yet to be applied.

The aim of this paper is twofold: on the one hand, it attempts to empirically assess the determinants of piracy, paying special attention to the effect of the legal framework on piracy. On the other, it develops a new measure of software protection that attempts to capture the strength of software protection through a detailed consideration of each country's legislation, taking as a reference copyright law. Methodologically, this empirical study of 23 European countries over three periods of time (1994, 1997, and 2000) is the first study on piracy to use a panel data approach. One major advantage of using panel data rather than conventional cross-sectional or time series data is that it gives researchers a larger dataset point and enables them to control for unobserved country heterogeneity. Larger dataset points help to increase the number of degrees of freedom and reduce the collinearity among the variables, thereby improving the efficiency of parameter estimates (Baltagi, 2001; Hsiao, 2003).

The rest of this paper is organized as follows: Section 1 reviews the theoretical and empirical arguments for the potential effects of the legal framework on piracy. Section 2 discusses the current legal situation of copyright protection for computer programs and describes the strength of software protection. Section 3 outlines the econometric model and describes the data to be used in the empirical model. Section 4 presents the results of the empirical analysis. The final section concludes the paper and proposes guidelines for future studies of piracy.

## 1. The impact of the legal framework on piracy

Even though several empirical studies consider the possible link between the legal framework and piracy rates, in general the mechanisms through which the legal framework may influence piracy levels are either not properly discussed or are little understood. Previous research suggests that a country's membership in any international convention may signal that its national law recognizes the principle of national treatment and certain periods of protection, and such membership may thus influence the level of intellectual property violation in a particular country (Park, 2001; Ronkainen and Guerrero-Cusumano, 2001). If this hypothesis were accepted, then a relationship between this variable and piracy would be expected.

Several theories provide useful theoretical foundations for the hypothesis that the legal framework may impact piracy rates. Perhaps the most obvious is Landes and Posner's (1989) traditional economic theory of copyright. In their model, the degree of copyright protection can be enforced at a certain cost for the copyright owner. Thus, theoretically, there would be no piracy in the economy because, optimally, copies would be driven out of the market. However, in practice, piracy is a widespread phenomenon in the market for information goods. There are two plausible explanations for this observation. First, the level of copyright protection is too low, in which event a positive number of illicit copies are produced. Second, the relationship between the costs and the level of copyright protection is probably non-linear. Therefore, if enforcement costs increase with the level of copyright protection, illegal

copying may exist in equilibrium. In light of this non-linearity, one might expect a relationship between the level of copyright protection and piracy.

Another source of hypotheses about the practice of illegal copying is criminological theory. Ehrlich's (1973) economic theory of crime proposes that the decision to commit a crime is a rational choice involving the optimal allocation of resources. Thus, the opportunities and rewards can be represented in terms of the costs and benefits of legal and illegal activity, and those incentives can be used to deter criminals. With regard to the act of software piracy, deterrent controls may be associated with the role of national governments in enacting copyright laws against pirates. For instance, national governments can upgrade software piracy from a non-serious offense to a serious felony, increase the severity of punishment (higher penalty) for copyright violations, and restrict individual opportunities to make or distribute copies of computer programs for unauthorized users. From this perspective, one might assume that changes in the copyright system could have substantial repercussions on individuals because they would influence the legal and illegal gain from piracy. Thus, a relationship between piracy and current IPR measures seems likely.

In terms of empirical work, the question of whether intellectual property protection has any impact on piracy seems to be answered with a mild affirmative. However, the extant literature relies on cross-sectional estimation methods, and studies vary significantly in terms of the countries studied, the period of analysis, the measure of IPR protection (international membership dummies or index), the dependent variable (dichotomous or continuous), the functional form of the explanatory variables (with or without quadratic terms), and the set of explanatory variables included in the models.

Burke (1996) uses macro level data from 1995 for 49 countries to investigate the importance of intellectual property protection and piracy levels in the audio software industry. He measures the strength of IPR protection for any particular country using membership in international treaties and duration of membership (e.g., Berne, 1887; Rome, 1961; Geneva Phonogram, 1971). Contrary to the hypothesis suggested by the economic theory of copyright, his results indicate that there may be no association between the level of protection enjoyed in any particular country and piracy. In contrast, Papadopoulos (2003), using the same proxy variable for IPR protection in a sample of 84 countries, finds that piracy shares in the sound recording market decrease with the strengthening of intellectual property rights protection. Moreover, by including in his model an index of property rights as a proxy for copyright enforcement, Papadopoulos purports to show that countries which tend not to protect property rights are likely to be less open to the notion of protecting intangible property. This finding would suggest a negative relationship between the property rights index and piracy. However, strictly speaking, this measure represents not a country level of copyright protection but rather the risk involved in enforcing contracts in any particular nation. Moreover, Papadopoulos's estimation is likely to be subject to simultaneity bias because he regresses the piracy market share on an index of property rights likely to be a function of the share.

Van Kranenburg and Hogenbirk's (2005) recent contribution to the piracy literature examines the determinants of piracy in the multimedia, entertainment, and software industries. Although the effect of IPR protection on piracy is not the primary focus of their paper, they specifically construct a measure of strength for 44 national IPR systems in the year 1998. They examine three conditions related to IP laws which are scored with a value between zero and one: (1) membership in international treaties (Berne, 1887; Paris, 1883; Universal Copyright Convention, 1952; European Patent Convention, 1973; Patent Cooperation Treaty, 1970), (2) availability of patent protection in the national law and (3) availability of copyright protection in the national copyright law. The country's score is the number of conditions satisfied (number of ones assigned) divided by the maximum number of conditions to be satisfied.

Thus, the index varies from one (strong protection) to zero (low protection).<sup>7</sup> Their main finding is that countries with stronger copyright system show lower piracy rates. Moreover, this effect seems to be relatively larger in the entertainment software industry and among business software applications than in other copyright industries.

## 2. Direct measure of software protection

Before measuring the strength of software protection, it is important to describe the current legal situation of copyright protection of computer programs in Europe.<sup>8</sup>

### 2.1. Background

A council directive on the legal protection of computer programs was adopted in May 1991.<sup>9</sup> This directive adds continuity to the Maastricht Agreement,<sup>10</sup> by which lower national courts may refer rulings on EU law to the Court of Justice so that a uniform jurisdiction can be established for all member states. Before this software directive, it was unclear in some member states whether computer programs enjoyed protection under copyright law. For example, prior to the directive's implementation, the laws in Italy and Portugal did not clearly protect computer programs.<sup>11</sup> Under the directive, the standard that all EU member states were required to adopt was the copyright protection of software as "literary work" in line with other international agreements. That is, the directive only protected the expression of a computer program (operating systems, application programs, programming language, and manuals) against unauthorized duplication but excluded the ideas and principles underlying it.<sup>12</sup> Unlike the U.S. copyright law, the software directive specifically chose not to include a definition of computer program for fear that the definition would be outdated in a few years because of rapid technological evolution in software development.<sup>13</sup> Indeed, most national copyright legislations do not provide a definition of computer software, even though such software is included in the list of protected works. Moreover, computer programs must be "original" in the sense that they are the author's own intellectual creation.<sup>14</sup> Nevertheless, national disparities still remain in the interpretation of the term "originality."<sup>15</sup>

<sup>7</sup> For the purposes of this study, this measure is not appropriate because it does not capture changes in IPR protection over time, and it assesses the strength of intellectual property laws in general and does not explicitly incorporate the enforcement dimension.

<sup>8</sup> In law, computer programs are considered hybrid entities: whereas on the one hand, the program itself can be protected by copyright, on the other, the ideas and algorithms involved might be patented. Nonetheless, copyright seems to be the strongest IP measure to fight software piracy (Tysver, 2000).

<sup>9</sup> See Council Directive 91/250/EEC on the legal protection of computer programs, May 1991 [hereinafter, Software Directive]

<sup>10</sup> See Article 177 of the Maastricht Agreement.

<sup>11</sup> Italian Decree Law No. 518 of 29 December 1992; Portuguese Decree Law No. 252 of 20 October 1994.

<sup>12</sup> See Software Directive, art 1.2. The U.S. Copyright Act (1976), in contrast, excludes any idea, procedure, process system, method of operation, concept principle and discovery from copyright.

<sup>13</sup> In the words of Samuelson (1999), "the lack of definition could allow for the protection of computer programs outside the scope of this directive."

<sup>14</sup> See Software Directive, art. 1.

<sup>15</sup> For instance, in Germany an additional condition to qualify for copyright protection is the achievement of a required level of creativity ("Schöpfungshöhe"). In the U.K., a work is original if there is some element of skill and labour and the work has not been copied.

Under the software directive, the copyright owner has the right to prevent certain uses of work as well as the right to authorize use. Types of use are the right to reproduce the work on a physical support, the right of public performance, and the right of translation and adaptation.<sup>16</sup> Under certain circumstances, the rights of the copyright owner are limited to ensure an adequate balance between the interests of software users and copyright holders. These restrictions on the scope of exclusive rights are (1) back-up copies, (2) reverse engineering or decompilation, and (3) private copying.<sup>17</sup> To ensure that authors reap some benefits from the work's creation, copyright protection for computer programs is established on creation of the work and lasts for 50 years after the author's death.<sup>18</sup>

## 2.2. Description of the index

This section describes the construction of a new index of the strength of software protection in Europe. Such construction is a complex task because any intellectual protection measure might be subject to subjectivity and criticism. As Maskus (2000a) points out, "it is difficult to capture the economic incentives afforded by a system of laws such as IPR, in a meaningful index" (p. 15). The information used here to construct the index is drawn from available national copyright laws. Obviously, the proposed measure is only intended to reflect the potential of any particular country to comply with the general provisions of software protection and not its actual implementation of such provisions.<sup>19</sup> Moreover, this index is not a measure at a single point in time but rather allows the capture of changes over time. Thus, even as laws change, it will still be possible to compute the exact values for each time period using the current copyright law. Nevertheless, in constructing an index to indicate the strength of IPR, two problems must be taken into account. First, the choice of variables to be included in each category or component is obviously disputable. Second, each category should be weighted according to its importance, but the lack of a theoretical framework indicating the relative importance of each category requires the introduction of subjective criteria. One common procedure is to weight each category or component equally; therefore, this convention is adopted here.<sup>20</sup> The proxy for the strength of software protection consists of two categories: *membership in international copyright treaties* and *enforcement provisions*. The following discussion provides a brief description of each of these categories together with the rationale for their use.

<sup>16</sup> Non-economic rights or moral rights that exist in various European countries (for example, Austria, Italy, Russia, Spain, Slovenia).

<sup>17</sup> See Software Directive, articles 5.6. In contrast, U.S. Fair Use law objects to reverse engineering or decompilation.

<sup>18</sup> A uniform term of protection of lifetime plus 70 years was enforced in the E.U. Member States with the introduction of the directive Harmonizing the Term of Protection of Copyright and Certain Related Rights (93/98/EEC) in October 1993. In the U.S., the term is shorter—the author's lifetime plus 50 years, enacted in the U.S. Copyright Act (1976).

<sup>19</sup> Several measures or indices of IPR regimes have emerged in the literature. However, these refer specially to patents. Ginarte and Park (1997) rank the national IPR regimes of 100 countries. To compute a country's ranking, five different categories of patent laws are considered: (i) extent of coverage, (ii) provisions for loss of protection, (iii) membership in international patent agreements, (iv) enforcement mechanisms and (v) duration of protection. Each category is coded between zero and one. A country's score is the unweighted sum of all these categories. Thus, the index ranges from zero to five with higher values indicating stronger patent protection. Currently, this index is the most useful way to evaluate how IPR laws are written "on the books."

<sup>20</sup> Another procedure is to use objective methods such as principal component or factor analysis. This application is, however, beyond the scope of this paper. See Lesser (2001) for an application of these techniques to the construction of an IPR score.

The *international membership* category is quite likely to reflect the extent to which one country does or does not tolerate intellectual property violation, and the willingness of a country to adhere to international principles such as non-discrimination. This category consists of the following variables: (i) the Berne convention for the protection of artistic and literary works (1886), (ii) the World Intellectual Property Organization Copyright Treaty (WCT) (WIPO, 1996), and (iii) the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs, 1994). The Berne Convention is the oldest international agreement, providing for uniform global protection of literary and artistic works. Its basic underlying principles are national treatment, automatic protection, and independence of protection. Even though the Berne convention does not implicitly include computer programs, the definition of artistic and literary works is extremely broad and can thus encompass computer programs.<sup>21</sup> The World Intellectual Property Organization (WIPO), fearing online copyright infringements, adopted two treaties to extend the protection of copyright and related rights: the WIPO Performances and Phonograms Treaty and the WIPO Copyright Treaty (WCT). The WCT covers the following issues: the rights applicable for the storage and transmission of works in digital systems, the limitations on and exceptions to rights in a digital environment, and rights management information. Computer programs are also protected under the WCT within the meaning of the Berne convention.<sup>22</sup> The Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPs) follows the GATT conditions of adopting the multilateral constraints of non-discrimination and a commitment to transparency. However, this agreement is also an innovation, having established certain minimum standards of protection—essentially adapting them to the higher U.S. and European standards—and guidelines for enforcement<sup>23</sup>, while giving members some discretion as to how these standards are implemented (Primo Braga, 1996). Computer programs are also protected under copyright as literary works.<sup>24</sup>

Table 1, which illustrates country membership in the three international treaties as of 2000, may give the erroneous impression that the legal structure and enforcement mechanisms for IPR are quite strong in European countries. For instance, Greece and Poland are members of all conventions, but both share high levels of illegal copying. Thus, having international membership may be a necessary condition for fighting piracy, but it is not a sufficient one. Countries that are signatories to all three treaties earn a score of 1 in the international membership category, whereas those who are signatories to just one treaty earn a score of 1/3. Thus, the international membership category ranges from 0 (no membership in any international treaty) to 1 (membership in all international treaties).

No measure of a country's IPR protection would be complete without consideration of enforcement provision (Samuelson, 1999; Ostergard, 2000). The enforcement of IPR encompasses two tasks: preventing infringement by free-riders and disciplining attempts by copyright holders to extend rights beyond the terms of the grant (Maskus, 1998). Moreover, according to the TRIPs agreement, it is not enough to have laws "on the books"; nations must prosecute criminal offences under the agreement. The enforcement category allows for differences across countries in civil procedures related to computer software and so consists of the following provisions: (i) ex-parte civil search orders, (ii) border measures, and (iii) remedies. Nevertheless, this category does not indicate whether and to what extent countries

<sup>21</sup> See Article 2 (1).

<sup>22</sup> See WIPO Copyright Treaty, art.4.

<sup>23</sup> See Articles 41-61 of TRIPs.

<sup>24</sup> See Article 10 (1) of TRIPs.

**Table 1** Membership in international intellectual property rights treaties as of 2000

Country	Treaties		
	Berne	WCT	TRIPS
Western Europe			
Austria	Yes	Yes	Yes
Denmark	Yes	Yes	Yes
Finland	Yes	Yes	Yes
France	Yes	Yes	Yes
Germany	Yes	Yes	Yes
Greece	Yes	Yes	Yes
Ireland	Yes	Yes	Yes
Italy	Yes	Yes	Yes
Netherlands	Yes	Yes	Yes
Norway	Yes	No	Yes
Portugal	Yes	Yes	Yes
Spain	Yes	Yes	Yes
Sweden	Yes	Yes	Yes
Switzerland	Yes	Yes	Yes
United Kingdom	Yes	Yes	Yes
Eastern Europe			
Bulgaria	Yes	No	Yes
Czech Republic	Yes	No	Yes
Hungary	Yes	Yes	Yes
Poland	Yes	No	Yes
Romania	Yes	Yes	Yes
Russia	Yes	No	No
Slovakia	Yes	Yes	Yes
Slovenia	Yes	Yes	Yes

Source: World Intellectual Property (WIPO), and World Trade Organization (WTO).

Note: The Berne Convention for the Protection of Literary and Artistic Works, the World Intellectual Property Organization Copyright Treaty (WCT), and the Agreement on Trade Related Aspects of Intellectual Property Rights (TRIPS).

currently enforce the laws that are on the books.<sup>25</sup> In fact, this omission may not be important, as it seems that countries with strong statutory laws tend to be the ones that actually carry out the laws (Park, 2001).

The term *ex-parte civil search order* refers to a legal search procedure conducted upon application by the copyright holder without prior notice filed in a court, wherein the copyright

<sup>25</sup> It would be ideal to dispose of credible information about penalties, prison terms and real mechanisms of protection. However, data on these aspects are almost non-existent, and thus the strength of software protection in practice can only be measured in an indirect way. One alternative would be to use the United States Trade Representative (USTR) Special 301 reports, which contain information about enforcement practices with a special focus on copyright and trademarks. However, the reliability of this proxy can be questioned for several reasons. First, as emphasized by one of the referees, USTR reports are biased towards U.S. interests and are likely to be more political than statistical in nature. Second, they are based on the distance of national laws and enforcement in comparison to the U.S. activity, which is taken as the benchmark.



owner alleges an infringement of a right (e.g., TRIPs article 50).<sup>26</sup> As judicial procedures may take a fair amount of time, it is crucial for the judicial authorities to provide such provisional relief to stop alleged infringement immediately. Whereas in some countries (e.g., Slovenia, the United Kingdom, Germany), an ex-parte civil search is granted to copyright holders, in others such provisions are either argued to exist (e.g., the Czech Republic, Denmark) or have not really been transposed into the national laws (e.g., Norway, Russia, Poland).

*Border measure* refers to acts whereby the copyright holder may file an application to customs to suspend the entry of pirated goods. In general, any goods that a court rules have been pirated will be destroyed or rendered to the copyright holder.<sup>27</sup> However, in some countries (e.g., Russia, Romania, Greece), there are no provisions for border measures under copyright law. *Remedies* include legal measures such as seizure and destruction of infringing copies, as well as materials and equipment used for their reproduction (see, for instance, TRIPs article 46).<sup>28</sup> Most countries provide such specific legal provisions, although a few do not (e.g., Greece).<sup>29</sup>

The corresponding enforcement category includes three conditions based on the three measures and coded one (yes = 1) if one condition is satisfied and zero (no = 0) otherwise. Thus, the enforcement category value for a country is the number of conditions satisfied (number of ones received) divided by the maximum number of conditions to be satisfied. For instance, if a country satisfies just one condition, it receives a value of 1/3; if two conditions, a value of 2/3; and if all three conditions, a value of 1. A country's total index score is the unweighted sum of the assigned values for both international membership and enforcement provision. Thus, the overall index ranges from 0 (no protection) to 2 (strongest protection).

### 3. Model and data

#### 3.1. The model

To study the effect of software protection on piracy rates, I specify a reduced form regression equation, using piracy rate as the dependent variable. Admittedly, figures on piracy are likely to be underestimated because a large number of software applications are sold without the computer hardware (Traphagan and Griffith, 1998; Husted, 2000; Van Kranenburg and Hogenbirk, 2005). Nevertheless, this data source is the most reliable for cross-country comparisons and is commonly employed in the research (e.g., Husted, 2000; Marron and Steel, 2000; Van Kranenburg and Hogenbirk, 2005).

<sup>26</sup> This rule derives from the English case *Anton Piller K.G.V. Manufacturing Process LTD* in 1976.

<sup>27</sup> The TRIPs agreement also recognizes the importance of border enforcement measures (Articles 51 to 60). As regards European customs action against infringements of intellectual property rights, the legal framework is the Council Regulation 3295/94 of 22 December 1994. Its effects are extended to infringement of copyright and also to other similar rights to export and re-export. Lastly, the custom authorities were given greater scope for action and were allowed to act ex-officio. In 1999, Council Regulation No. 241/99 substantially amended the 1994 Regulation, broadening its scope to patents and supplementary certificates, as well as to the protection of community trademarks at customs via a uniform system of protection in all member states. Similarly, intervention was extended to infringing on goods whatever their customs status.

<sup>28</sup> It should be noted that other remedies may include indemnification of the person offended or publication of the judgement at the offender's expense. See, for example, Spain.

<sup>29</sup> TRIPs article 61 requires that criminal procedures be available at least for copyright and trademark infringements.

As regards the independent variables, because illegal copying may respond to legal tendencies towards or against protected IPR, an index of copyright software protection (as discussed above) is included to account for its effect as a representation of different levels of copyright protection for computer programs and to explain the degree of excludability. In addition, because national income is considered a strong predictor of intellectual property rights and protection, the real GDP per capita is included as another control variable to capture the level of economic development in a country. The rationale for this inclusion is as follows. Ginarte and Park (1997), Rapp and Rozek (1990), and Maskus and Penubarti (1995) all find that countries with high income have stronger patent protection. In contrast, intellectual property protection in less developed countries tends to be “shorter, less comprehensive, and much less vigorously enforced” (Richardson and Gaisford, 1996, p. s376). In their recent article, Shadlen, Schrank, and Kurtz (2005) note a relationship between income and intellectual property protection which may be thought of in terms of the demand and supply of intellectual property protection. On the demand side, as nations become wealthier, local producers devote more resources to innovative activities and are more likely to demand that national governments increase IPR protection. On the supply side, the degree of software protection may also depend on financial capacity: countries with a higher level of GDP per capita are able to provide stronger protection simply because they can afford to (Varian, 1998; Ostergard, 2000). Protection provision involves large fixed costs—for example, judicial courts and policing; therefore, countries with large financial resources are more likely than nations with fewer resources to provide it (Varian, 1998; Kanwar, 2002). For all these reasons, a negative correlation between GDP and piracy can be expected. Indeed, previous empirical research corroborates the negative impact of income on piracy (e.g., Gopal and Sanders, 1998, 2000; Holm, 2003; Husted, 2000; Marron and Steel, 2000; Ronkainen and Guerrero-Cusumano, 2001, among others). In addition, the relationship between the rate of piracy and GDP per capita may well be non-linear, with piracy first increasing then later declining as the level of per capita income increases. To shed some light on this issue, the square term of the real GDP per capita is included in the regression model based on the expectation that the coefficient on income term will be positive while its quadratic term will be negative.

Also controlled for are a number of potential determinants of piracy previously employed in the empirical literature, although with inconsistent results; in particular, the level of human capital, intensity of the inventive effort, and a country's trade dependence on the U.S. A human capital measure, secondary school enrollment, is used to capture the potential for the country to adopt and improve new technology (Nelson and Phelps, 1966). Research also provides evidence that education may increase the demand for IPR (Ginarte and Park, 1997; Scalise, 1997; Marron and Steel, 2000). Moreover, educational outcome may evolve with institutional quality, and thus omitting this variable might attribute to our software protection index some effect more fundamentally related to education rather than protection. Based on the above arguments, a negative correlation between education levels and piracy may be anticipated; however, the empirical evidence on the effect of education on piracy rates remains controversial. For example, Marron and Steel (2000) fail to find support for this hypothesized relationship between education and piracy. Conversely, Depken and Simmons (2004) and Shadlen, Schrank, and Kurtz (2005) find a significant negative effect of a country's education level on software piracy rates.

It is also hypothesized that countries with a relatively high inventive activity (R&D) have an incentive to provide relatively stronger protection for intellectual property, a possibility

acknowledged in the formal literature (Frame 1987; Ginarte and Park, 1997).<sup>30</sup> Research evidence does show a negative (either significant or insignificant) effect of R&D on piracy (Marron and Steel, 2000; Shadlen, Schrank, and Kurtz, 2005). Therefore, in this model, R&D expenditure as a proportion of real per capita gross national product is used to control for the levels of inventive activity in any particular country.

Following Depken and Simmons (2004), it is also assumed that as a country's trade becomes increasingly dependent upon the U.S., the U.S. might increase pressure on the foreign government to enforce IPR. If U.S. trading partners feel pressure to enforce IPR, then a negative coefficient could be expected on this variable, especially as previous empirical research does find a significant negative relation between trade dependence and rate of piracy (Depken and Simmons, 2004; Shadlen, Schrank, and Kurtz, 2005). Thus, in this empirical analysis, trade dependence is measured by the proportion of a country's exports sold in the U.S. market.

Finally, it is very likely that, in any given country, important country-specific effects are related to piracy rates, including geography and persistent differences in piracy tastes not captured by the set of observed covariates included in the model's specifications. As noted above, ignoring these effects may lead to biased estimates of parameters. For instance, the index of software protection is likely to be correlated with the individual effects of cultural or institutional factors.<sup>31</sup>

Integration of all the above ideas and observations produces the following econometric model<sup>32</sup>:

$$\ln(PR_{it}) = \alpha_i + \beta_1 \ln(GDP_{it}) + \beta_2 (\ln(GDP_{it}))^2 + \beta_3 INDEX_{it} + \beta_4 EDUC_{it} + \beta_5 RD_{it} + \beta_6 TRADEP_{it} + \varepsilon_{it}, \quad (1)$$

where  $PR$  is the piracy rate in country  $i$  at time  $t$ ,  $GDP$  is the real  $GDP$  per capita expressed in 1995 U.S. dollars and adjusted via purchasing power parities,  $INDEX$  is the index of copyright software protection,  $EDUC$  is the secondary school enrollment,  $RD$  is the proportion of R&D expenditures on real  $GDP$  per capita, and  $TRADEP$  is the percentage of a country's exports to the U.S. The parameter  $\alpha_i$  denotes the individual specific effects, and  $\varepsilon_{it}$  is the classical error term.

The empirical analysis is carried out in several steps: the first step is to run a simple panel fixed effects regression on the level of economic development. The second step integrates the level of software protection as an additional explanatory variable. The third step examines non-linearities in the relationship between piracy and per capita income. The fourth step is a discussion and test of the robustness of these results to potential endogeneity, as well

<sup>30</sup> Although, there are other studies that empirically and theoretically examine the relationship between the strength of intellectual property protection in general and intensity of the innovative effort (see Evenson, 1990; Gould and Gruben, 1996; Schankerman, 1998; Park and Ginarte, 1997). Accounting for this potential endogeneity is, however, beyond the scope of this paper. Some formal discussion on this issue is found in the recent work of Kanwar and Evenson (2003).

<sup>31</sup> Cultural factors are also likely to play an important role when explaining differences in piracy rates across countries (Husted, 2000; Depken and Simmons, 2004). However, cultural norms are relatively stable over time, and this effect may already be picked up in our fixed effects approach.

<sup>32</sup> The model in Eq. (1) is also estimated including a linear time trend intended to capture a variety of factors including exogenous advances in technology and changes in piracy preferences. Coefficient estimates (not reported) maintain their sign and significance after the inclusion of a linear time trend, thus supporting the robustness of the results.

as the measurement error of the *INDEX* variable. The final step controls for the additional determinants of piracy suggested by previous literature, such as secondary school enrollment, R&D expenditures, and trade dependence with U.S. The next subsection discusses the data to be used to test these specifications.

### 3.2. Data

#### 3.2.1. Primary variables

Data on the variables used in the empirical analysis come from diverse sources.<sup>33</sup> Piracy rates are obtained from the International Planning and Research Corporation's (IPRC, 2003) annual report for the years 1994, 1997, and 2000.<sup>34</sup> Piracy rate is defined as the difference between software programs installed and software applications legally licensed.<sup>35</sup> The variable is reported as percentages, with 0 percent indicating no piracy and 100 percent indicating that all software installed is pirated. As shown in Table 2, there is a geographic spread of the piracy phenomenon. In some countries, like Russia (88%), almost all software is pirated, while in other countries like Denmark, Finland, and the United Kingdom, the share of illegal software in 2000 was below 30 percent. From 1994 to 2000, the average piracy rate declined from 67 percent to 47 percent; however, the reduction in piracy differs significantly between regions and within regions. For example, the average piracy rate declined from 58 percent to 38 percent (34.5%) in Western Europe and from 82 percent to 62 percent (24.5%) in Eastern Europe. Within sub-regions, the largest reductions were found in Denmark (46%) and Slovenia (36%), respectively. Interestingly, between 1994 and 2000, the ranking of the five top offenders in Western Europe (Greece, Spain, Ireland, Italy, and Portugal) and Eastern Europe (Russia, Bulgaria, Romania, Poland, and Slovenia) barely changed. In addition, even though piracy rates decreased in Greece from 87 percent to 66 percent and in Russia from 95 percent to 88 percent, these countries maintained their position as the nations with the highest share of illegal copying. Such vast disparities in copyright piracy may be explained by cultural values and economic factors. Indeed, the issue of piracy necessarily brings into focus the "informal economy"<sup>36</sup> because piracy, along with drug dealing and prostitution, is an illegal aspect of informal activity. Yet, even though software piracy belongs to the informal domain, its products reach to the legal sector, often affecting "legitimate" market conditions. A brief comparison across countries using informal sector size as a percent of GDP illustrates this point.<sup>37</sup> For instance, informal sector work amounts to 27–28 percent of GDP in Greece, Italy, and Portugal but to 8–10 percent of GDP in Switzerland and Austria. By far the largest informal economy is found in Russia at 46 percent, followed by Bulgaria at 37 percent, and Romania at 34 percent. Finally, the average size of the informal economy in Eastern Europe is larger than in Western Europe, 38 percent and 17 percent, respectively. In general, the lower the piracy rate, the lower the size of the informal

<sup>33</sup> The definitions and data sources of the variables are given in the Appendix.

<sup>34</sup> The data are available on <http://www.bsa.org/globalstudy2003/>

<sup>35</sup> Further information on the methodology employed to construct piracy rates can be found in the recent report on Global Software Piracy elaborated by the International Planning and Research Corporation (IPRC, 2003).

<sup>36</sup> We do not discuss the issue of measurement of the informal sector. For a review of the methods found in the literature for measuring the shadow economy, see, for example, Tanzi (1999), Elliat and Zinnes (2000) and Schneider (2005).

<sup>37</sup> Data taken from Schneider (2005)

**Table 2** Estimated piracy rates

Country	Piracy rate (%)		
	1994	1997	2000
<b>Western Europe</b>			
Austria	47	40	37
Denmark	48	32	26
Finland	53	38	29
France	53	44	40
Germany	48	33	28
Greece	87	73	66
Ireland	74	65	41
Italy	69	43	46
Netherlands	64	48	40
Norway	53	46	35
Portugal	65	51	42
Spain	77	59	51
Sweden	54	43	35
Switzerland	38	39	34
United Kingdom	42	31	26
Average	58.1	45.7	38.4
<b>Eastern Europe</b>			
Bulgaria	94	93	78
Czech Republic	66	52	43
Hungary	76	58	51
Poland	77	61	54
Romania	93	84	77
Russia	95	89	88
Slovakia	66	58	45
Slovenia	96	76	61
Average	82.7	71.4	62.1

*Source:* International Planning and Research Corporation. Eighth Annual BSA. Global Software Piracy Study. Trends in Software Piracy 1994–2002 (IPRC, 2003).

economy. However, this apparent correlation, while informative, is of limited use for statistical analysis.<sup>38</sup>

Legal information for the construction of the software protection index comes from various sources, primarily the World Intellectual Property Organization (WIPO), the United Nations Educational, Scientific, and Cultural Organization (UNESCO), and the World Trade Organization (WTO). This information is supplemented by the Civil and Criminal Codes, as well as by national copyright law. Table 3 displays summary statistics on the index of copyright software protection for 23 countries over the three time periods under consideration. Throughout these periods, the average degree of protection increases for both the overall

<sup>38</sup> Addressing this issue requires the use of statistical models to identify the possible directions of causality between piracy and the shadow economy.

**Table 3** Summary statistics of the index of copyright software protection

	1994	1997	2000
A. Full countries sample ( $N = 23$ )			
Mean	0.98	1.74	1.84
SD	0.38	0.40	0.30
CV	0.39	0.23	0.16
Minimum	0.33	0.67	0.67
Maximum	1.33	2.00	2.00
B. Western countries sample ( $N = 8$ )			
Mean	0.54	1.38	1.63
Standard. Dev	0.25	0.49	0.41
CV	0.46	0.35	0.25
Minimum	0.33	0.67	0.67
Maximum	1	2	2
C. Eastern countries sample ( $N = 15$ )			
Mean	1.22	1.93	1.96
SD	0.16	0.14	0.12
CV	0.13	0.07	0.06
Minimum	1	1.67	1.67
Maximum	1.33	2	2

*Note:* The index of copyright software protection is on a scale from 0 (weakest) to 2 (strongest).

sample and all subgroups of European countries. It should also be noted that, by the end of the sample period, the gap in IPR protection between Western and Eastern countries has narrowed considerably. Overall, taking as a benchmark the initial year of 1994, all countries have strengthened their copyright laws. As important, no country has registered a reduction in its software protection score.

The increase in protection levels over the three time periods is most pronounced in Eastern countries, whose 1994 data show low levels of protection. This increase may be partly due to anticipation of the provisions of the TRIPs agreement and greater pressure to harmonize the IPR system. Moreover, the variation in software protection, as shown in the coefficients of variation (CV), decreases across the full sample as well as the subgroups of European countries. That much of the variation in the overall index appears to come from Eastern rather than Western countries reflects the reality that most protective measures were already available in Western countries at the beginning of the study period.

Table 4 shows the index values by country and year. However, it should be noted that countries receiving the same score may have copyright regimes that differ enormously. These differences in copyright laws would be accentuated by differences in the way national authorities interpret these laws (for instance, an infringement in one particular country may not be one in another) and ultimately by their enforcement. Indeed, some countries may not have the material or human resources to implement copyright law satisfactorily. Therefore, legal practices may have an impact on the amount of illegal copying. For example, in countries like Greece, Italy, and Spain, where effective protection of copyright software is lacking, penalties are almost negligible and prison terms rarely imposed. Moreover, judicial processes in criminal and civil copyright infringement are subject to long delays (United States Trade

**Table 4** Index of copyright software protection

Country	1994	1997	2000
Austria	1.33	2	2
Bulgaria	0.67	1	1.67
Czech Republic	0.67	1.33	1.67
Denmark	1	1.67	1.67
Finland	1.33	2	2
France	1.33	2	2
Germany	1	2	2
Greece	1.33	2	2
Hungary	0.67	2	2
Ireland	1.33	2	2
Italy	1.33	2	2
Netherlands	1.33	2	2
Norway	1.33	1.67	1.67
Poland	1	1.67	1.67
Portugal	1	2	2
Romania	0.33	1.33	1.67
Russia	0.33	0.67	0.67
Slovakia	0.33	1	1.67
Slovenia	0.33	2	2
Spain	1.33	2	2
Sweden	1	1.67	2
Switzerland	1.33	2	2
United Kingdom	1	2	2

Source: Author calculations.

Representative [USTR, 2001). A similar pattern emerges in Eastern countries. For instance, in Russia, even though in 1991 the government increased criminal sanctions for violations of copyright software, enforcement procedures are still inadequate. In only a few cases have high statutory fines been imposed (USTR, 2001).

As a final check of the model, I compute the correlation coefficient between my measure of copyright software protection in 1994 and Ginarte and Park's ([GP] 1997) measure in 1995.<sup>39</sup> This index is positively associated with GP's measure. The correlation coefficient is equal to 0.60 ( $P$ -value = 0.001), which gives some confidence that this proposed measure is capturing the extent of software protection across European countries.

### 3.2.2. Other variables

Data on *GDP* per capita in purchasing power parity (PPP) standards are extracted from the World Bank's World Development Indicators database (World Bank, 2003). Such data construction allows comparison across countries and over time. R&D expenditures are measured

<sup>39</sup> I would like to thank Walter Park for kindly providing the updated version of this index. This correlation coefficient was computed for 21 countries.

**Table 5** Regression results for  $\ln PR$  (fixed effects estimator)

Variables	(1)	(2)	(3)	(4)
$\ln(GDP)$	-1.769*** (9.39)	-1.156*** (6.43)	3.187*** (3.18)	3.276** (3.30)
$(\ln(GDP))^2$			-0.228** (3.92)	-0.233*** (4.00)
<i>INDEX</i>		-0.176*** (4.92)	-0.188*** (5.40)	-0.205*** (5.34)
<i>EDUC</i>				-0.001 (1.11)
<i>RD</i>				-0.043 (0.51)
<i>TRADEP</i>				0.006 (0.47)
Constant	22.568*** (11.18)	16.308*** (8.64)	-4.041 (0.94)	-3.796 (0.89)
Significance of individual dummies	12.73 (0.000)	16.57 (0.000)	20.07 (0.000)	17.13 (0.000)
Hausman test (DF)	99.58 (1) (0.000)	31.04 (2) (0.000)	40.61(3) (0.000)	76.59(6) (0.000)
Turning point			US\$ 1075	US\$ 1112
# of observations	69	69	69	69
Adjusted $R^2$ (overall)	0.5412	0.5650	0.5906	0.6022

*Notes:* All estimations were carried out using STATA v 8.0. *DF* = degrees of freedom. Country dummies were included in all regressions but not reported. Constant term is an average of the country specific effects. *T*-statistics (heteroskedastic-consistent) in parentheses. \*\*\*Statistically significant at 1%, \*\*Statistically significant at 5%, and \*Statistically significant at 10%.

by the share of the real *GPD* per capita, taken from the same database (World Bank, 2003). The data for secondary school enrollment can also be obtained from the World Bank's World Development Indicators database (World Bank, 2003). However, because of the non-availability of data on secondary school enrollment and R&D expenditures for the sample period, the average values of these variables are computed. Annual information on exports to the U.S. and Canada is taken from the United Nations Conference on Trade and Development (UNCTAD, 2004).

These data are used to construct a panel data set for 23 countries during the years 1994, 1997, and 2000. Only three periods of time are selected because laws are not expected to vary much annually and the earliest data on software piracy date back to 1994. The resulting sample includes 15 Western and 8 Eastern countries.<sup>40</sup> Descriptive statistics for all variables included in the regression analysis are provided in the Appendix.

<sup>40</sup> Belgium and Luxembourg are excluded because piracy data for these countries are merged and therefore do not match with data on the explanatory variables.



#### 4. Estimation results

Preliminary investigation shows that the fixed effects model performs better than the constant intercept as evidenced by the  $F$ -test (reported in Table 5), while the random effects model also performs better than the constant intercept model in terms of the LM test. However, the Hausman (1978) specification tests (reported in Table 5) reject the null hypothesis of orthogonality between the individual effects and the explanatory variables, suggesting that the fixed effects model is most appropriate. Further, in a White test performed to test for heteroskedasticity, the null hypothesis of homoscedasticity is rejected, meaning that even if the estimators remain unbiased, their significance is no longer reliable because the variance is biased. Therefore, a White's (1980) heteroskedasticity consistent covariance matrix estimator is used in the fixed effects approach to generate robust standard errors. The final empirical results for the fixed effects models are given in Table 5, which reports the coefficient and  $t$ -statistic for each variable.

The first regression is a simple regression of the  $PR$  variable on real  $GDP$  per capita. As shown in Table 5, the  $GDP$  variable, together with the set of fixed effects, captures 54 percent of the variation in piracy rates across countries, thus indicating good performance by the regression model. The estimated coefficient for per capita income is significant and negative. That is, higher levels of economic development are correlated with lower levels of piracy. This finding is consistent with most previous econometric analysis of piracy (e.g., Burke, 1996; Marron and Steel, 2000). As shown in column 1, a one standard deviation increase in per capita income reduces piracy by a 5.48 standard deviation. Nevertheless, the degree of economic development may be correlated with judicial and policing maturity, and it is possible to interpret it as a proxy variable for property right enforcement.

As the second regression (see column 2) reveals, it is not only the economic development that influences national piracy rates but also the current state of laws. The explanatory power is improved if the indicator of copyright software protection is included in the model. The  $R^2$  increases from 54 to 56 percent. With respect to this variable of interest, as expected, the index of copyright software protection ( $INDEX$ ) is negatively and significantly associated with piracy at conventional significance levels, supporting the hypothesis that the legal framework impacts piracy rates. That is, countries that provide stronger protection through copyright law for computer programs tend to have lower piracy levels. Comparing these figures with those in column 1, the income coefficient drops almost 36 percent from  $-1.769$  to  $-1.156$ , even while maintaining its significance at the 99 percent level. Column 2 also shows that a one standard deviation increase in  $INDEX$  decreases piracy by a 0.26 standard deviation. This negative effect is also observed in recent cross-sectional studies employing membership dummy variables as proxy for IPR protection (Van Kranenburg and Hogenbirk, 2005). It is also worth noting that the strength of software protection has the lowest standardized effect.

Column 3 presents the estimates of the baseline model that has piracy as a quadratic function of per capita income in order to capture non-linearities.<sup>41</sup> As argued earlier, there is no reason to assume that the relationship between piracy and income is linear. Adding the per capita income squared does not alter the estimation results. The coefficient of copyright software protection variable has a negative sign and is significant at the one percent level. Per capita income has a positively significant effect at the one percent level, and its squared term has a negatively significant effect at the one per cent level on piracy rates. This finding

<sup>41</sup> We also examine the non-linear effect of copyright software protection but find no significance.

can be interpreted to mean that illegal copying tends to increase initially, but, once countries reach some threshold value of per capita income, their development generates improvement in the protection against piracy.<sup>42</sup> Thus, there is apparently a quadratic relationship between *PR* and *GDP* reminiscent of the well-known environmental Kuznets curve (EKC) between income and pollution (Grossman and Krueger, 1995), in which pollution increases with per capita *GDP* to some point, after which, while *GDP* continues to increase, pollution tails off. Here, adding the squared term explains about 60 percent of the variation in piracy rates across countries; however, the net effect of the degree of economic development on piracy rates depends on the initial level of income. It is straightforward to compute that the curve reaches its maximum level at  $\ln(GDP) = 6.98$ , which translates into a real *GDP* per capita of \$1,075. It should be noted that the real *GDP* per capita is greater than \$1,075 for all countries in the sample for the years 1994, 1997, and 2000. This figure implies that the rate of piracy should decrease in almost every country included in the sample in response to an increase in the real *GDP* per capita.

Thus far, there appears to be a negative relationship between copyright software protection, income, and piracy rates. Moreover, the results support an inverted *U*-shaped relationship between piracy and per capita income. Nevertheless, the risk of endogeneity bias stemming from a simultaneous causality between piracy and legal protection must be discussed. Laws influence piracy but so do many other factors, including copying ability and technological progress. High piracy may indicate economic dependency on copying; in which case, policy authority may not strengthen the laws. On the other hand, high piracy may affect private businesses or firms, who may then lobby for stronger laws. It is also reasonable to expect that the degree of endogeneity may not be severe if one takes into account that policy makers' response to changes in piracy may be delayed. Nevertheless, this variable may still be subject to measurement error. As mentioned above, gaps between the measured and current levels of copyright protection may result from lax enforcement practices, trade policies, industrial targeting, and so on. Such problems are usually dealt with through instrumental variable techniques using such instruments as the control of corruption index (Kaufmann, Kraay, and Mastruzzi, 2003) and infant mortality rate per 1,000 births (World Bank, 2003). The results of a two-stage least squares (2SLS) regression (not reported) are largely similar to the OLS results. All model parameters maintain the same sign and similar statistical significance, although the coefficient estimate of *INDEX* is somewhat smaller.<sup>43</sup> The coefficient on the value of the index of software protection ranges from  $-0.18$  (un-instrumented) to  $-0.14$  (instrumented).

Because the impact of the *INDEX* and *GDP* variable may reflect other variables not yet included in the regression model, the findings are further tested for robustness by the addition to the specifications of a number of other explanatory variables (see the last column of Table 5). These include secondary school enrollment (*EDUC*), R&D expenditures (*RD*), and trade dependence with the U.S. (*TRADEP*). All these variables except for *TRADEP* reveal the expected sign and are not statistically significant. The observation that *EDUC* remains insignificant, in particular, is consistent with the mixed empirical evidence from recent studies on the determinants of piracy (Marron and Steel, 2000; Depken and Simmons,

<sup>42</sup> Maskus (2000b) finds a curvilinear effect of per capita income on patent rights.

<sup>43</sup> A Durbin-Wu-Hausman test (see, Davidson & MacKinnon, 1993) indicates that the *INDEX* variable is exogenous (at a *p*-value of 30%). Our instruments appear to satisfy the statistical requirements: they satisfy the first-stage requirement, and the over-identification test does not reject the null hypothesis that the instruments are uncorrelated with the error term. In the first stage, the *F*-test is 10.40, exceeding the recommended value of 10.

2004). Computer hardware and software are likely to be a complement of education/human capital, but it is also reasonable to expect that it is the type of education (not necessarily education in general) that impacts piracy rates. For instance, technical education that provides technical skills is likely to lower the cost of piracy, which should increase piracy among software-literate groups.<sup>44</sup> This issue may require further research.

The results also indicate that the ability to innovate (*RD*) has a negative sign but a statistically insignificant effect on piracy rates, even though countries that spend a high proportion of national income on R&D expenditures tend to provide stronger protection. This result, which supports Marron and Steel's (2000) finding of a negative (but not significant) effect for R&D expenditures on piracy rates, may be partly attributed to small changes over time (that render it not totally constant) and the aggregation problem inherent in the use of total R&D expenditures. That is, the variable is almost constant over time but suffers an aggregation problem because of the use of R&D expenditures. The coefficient on *TRADEP* has a positive sign in the regression model but is not significant. That is, greater trade dependence with the U.S. tends to increase software piracy, a finding that contradicts those of previous panel data studies (Shadlen, Schrank, and Kurtz, 2005). Two explanations seem plausible for this lack of statistical significance. First, it is difficult to detect the effects of political pressure on software piracy over a relatively short period of time. Second, this external pressure might only be targeted towards major U.S. trading partners. If so, given that the sample includes only a few such nations (e.g., Germany, the United Kingdom), there is little reason to expect a significant effect of such a measure on piracy.

In sum, including these additional covariates does not significantly alter either the (absolute) magnitude of the coefficients on per capita income and index of copyright software protection or the predicted inverted *U*-shaped relationship between software piracy and per capita income.

## 5. Conclusions

The contribution of this paper is twofold. First, it uses a rich dataset to examine the effect of software protection on rates of piracy. Although previous research does provide valuable insights into pirate behaviors, these studies suffer from the omitted variable problem. To remedy this omission, this analysis applies an econometric model (panel data) for 23 European countries over three annual periods. The advantage of the panel data technique is that it allows the omitted variable bias to be controlled for and improves the accuracy of parameter estimates. The second contribution is the construction of an index of copyright software protection across European nations. Whereas a large number of empirical applications use a crude indicator of IPR protection, it is argued here that the use of a specific measure of software protection is more convincing.

The empirical results reveal that copyright software protection is significantly related to piracy rates. In addition, in accordance with previous cross-country and panel data studies on piracy, per capita income appears to have a negative significant effect on piracy rates. Moreover, there is a quadratic relation (an inverted *U*-shaped curve) linking piracy and per capita *GDP*. The results also support previous findings of no significance for education, R&D expenditures, or external pressures (i.e., trade dependency).

<sup>44</sup> See Holm (2003) for a discussion of this issue.

The present study has three major policy implications. First, the findings imply that improving economic development may play an important role in lowering rates of piracy. Second, it appears that, whereas some piracy is inevitable during the early stage of development, the rate of piracy may be minimized at a later stage through the incentives provided by the development itself. Third, the results indicate that policies aimed at guaranteeing legal provision of the tools necessary to protect software would certainly contribute to curbing the software piracy problem.

In all, this exercise should be seen as a first attempt at a more comprehensive understanding of copyright systems across countries. In addition, the study helps to identify the data limitations that need to be addressed in future work. Specifically, future research should use a larger panel dataset that includes more countries and time periods so as to derive more solid conclusions on the impact of software protection on piracy levels. In addition, future studies that attempt to estimate the impact of software protection on piracy rates must carefully consider other forms of IPR (such as trade secrets and patents). Another natural extension would be to carefully consider the weights attached to each component in the index constructed because these assumptions may impact the results. Even though addressing this question in detail is beyond the scope of this paper, it is suggested that statistical techniques like principal component analysis might help researchers obtain appropriate weights. Finally, because piracy affects different information goods, the effect of intellectual property protection might be expected to depend on the kind of information goods referenced. Therefore, future studies should make it a priority to examine the link between legal protection and piracy in multiple copyright industries.

## Appendix

**Table A1** Sources and definitions

Variable	Definition	Source
PR	Piracy rate (%)	International Planning and Research Corporation (IPRC, 2003)
GDP	Real GDP per capita (in 1995 \$ US)	World Development Indicators (World Bank, 2003)
INDEX	Index of copyright software protection	Author's construction
EDUC	Secondary school enrollment	World Development Indicators (World Bank, 2003)
RD	R&D expenditures (share of GDP)	World Development Indicators (World Bank, 2003)
TRADEP	Exports to U.S. and Canada as percent of total exports	UNCTAD, <i>Handbook of Statistics</i> (2004)
Control of corruption	Index of control of corruption	Kaufmann, Kraay, and Mastruzzi (2003)
Infant mortality rate	Number of infants dying before reaching one year of age per 1,000 live births in a given year.	World Development Indicators (World Bank, 2003)

**Table A2** Summary statistics of variables

Variable	Obs	Mean	SD	Minimum	Maximum
PR (%)	69	56	19.405	26	96
GDP (\$ US)	69	18526.67	13115.24	1310	46777
INDEX	69	1.523	0.526	0.33	2
EDUC	69	105.439	18.187	72.211	157.092
RD	66	1.543	0.861	0.37	3.669
TRADEP	69	6.991	3.682	1.557	17.699
Control of corruption	69	1.223	0.990	-1.049	2.578
Infant mortality rate (1,000 births)	69	7.615	4.727	3.2	23.9

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