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The (Anti-)Competitive Effect of Intellectual Property Rights

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Abstract

We test whether intellectual property rights (IPRs) foster or hinder innovation by estimating IV structural equations for a large sample of Swiss firms. We find that better appropriability conditions at the industry level raise the number of competitors. However, conditional on the given industry structure, individual firms face fewer competitors, if they actually use IPRs. The further impact of fewer competitors is to raise R&D, when initial competition is strong, but to reduce it, when initial competition is weak ("inverted U").

JEL Codes: O31, O32, O34, D22

Key Words: patents, innovation, competition, simultaneous system

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1 Introduction

Intellectual property rights (IPRs) are meant to foster innovation. But there is clearly a trade-off between two crucial factors: (i) the impact of IPRs on competition; and, (ii) that of competition on innovation. Both add considerable complexity to the problem. For example, the use of IPRs may reduce competition for the individual firm. At the same time, the widespread usability of IPRs in an industry may protect small and innovative firms against the dominance of large competitors. We thus must expect independent and potentially opposite effects of IPRs at the level of industries and for individual firms. The second complication arises from the endogeneity of competition and innovation, where the question how competition affects R&D incentives has been highly controversial, repeatedly shifting claims for either a negative or positive impact, or more recently, an inverted-U relationship.[1]

The empirical evidence is surprisingly mixed.[2] We believe this emanates from the fact that usually the two impacts are jointly observed and not sufficiently disambiguated in the research designs. In short, competition affects the incentives to invest in R&D, the success of which determines the use of IPRs, which then feeds back on competition. Endogeneity is therefore a major issue. Our objective is therefore to separate these effects by expanding the structural model of competition and innovation introduced in Peneder & Wörter (2014) and adding an equation for the individual firms' use of IPRs. More specifically, we estimate a system of simultaneous equations relating: (i) IPR use; (ii) competition; (iii) R&D effort; and, (iv) innovation outcomes for a large sample of companies responding to the Swiss Innovation Surveys from 1999 to 2015.

2 Hypotheses

Our approach combines a core Schumpeterian model issuing from the innovation literature with a systems equation empirical strategy. We thus nestle our research within the literature on IPRs, competition and innovation, and aim to represent the model by a series of assumptions and hypotheses meant to capture those effects. By this distinction, *assumptions* (A) refer to relationships that have already been explained and tested on different data (but are nevertheless needed to close the model). In contrast, we refer to *hypotheses* (H), when the focus is on core impacts related to IPRs. Figure 1 summarizes their joint structure in the form of a probabilistic graphical model. Arrows indicate the presumed direction of causal impacts. Variables in circles are endogenous, those put in squares represent selected exogenous factors.

[1] Kamien & Schwartz (1976), Aghion et al. (2005).
[2] Lerner (2009), Bessen & Hunt (2007), Gallini (1992).

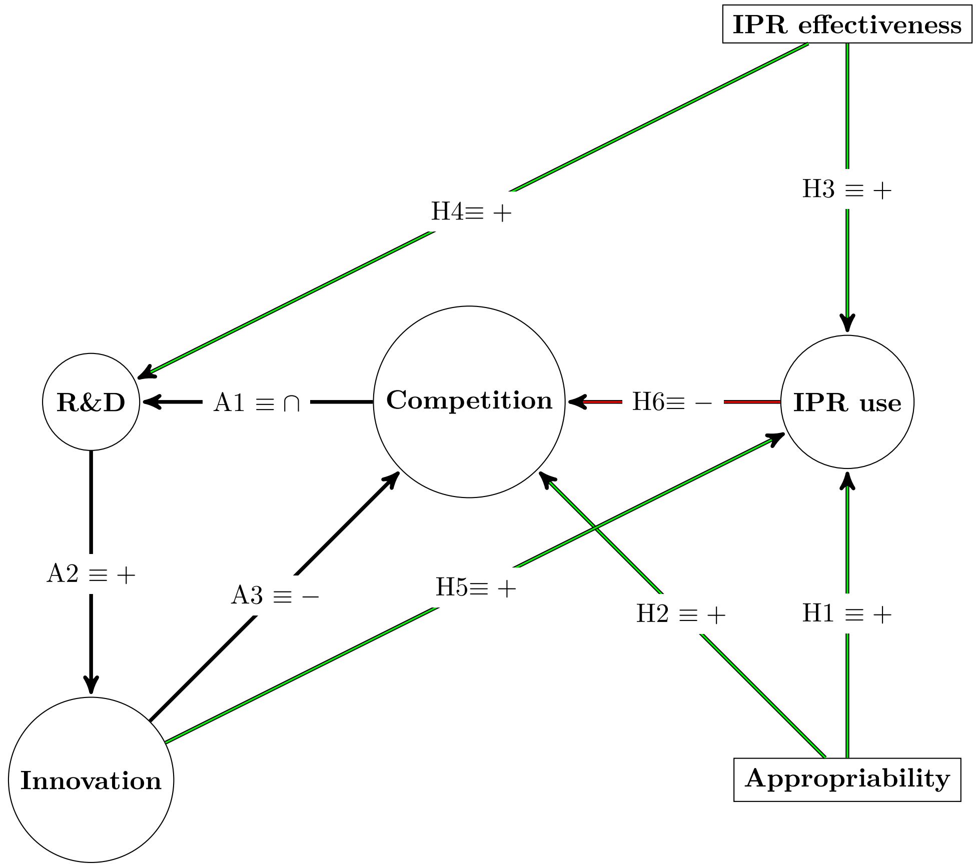

Figure 1: Skeleton of postulated causal graph for patent IPRs and competition.

Note: Endogenous variables are in circles; selected exclusion restrictions are rectangular. Vector of control variables X omitted. A for assumptions on the basic model; H represent hypotheses relating to IPRs.

The basic model builds on the following assumptions: first, competition affects the R&D effort, possibly by an inverted-U relationship ($A1$). Second, more R&D effort raises the probability of successful innovation ($A2$). Third, innovation allows a firm to pull away from competition ($A3$). In contrast, the following hypotheses relate to the determinants and impacts of IPRs: if industries offer favourable appropriability conditions, then firms are more likely to use IPRs ($H1$) and the market can support more competitors ($H2$). Furthermore, if firms perceive IPRs to be effective, then they are more likely to use them ($H3$) and tend to spend more on R&D ($H4$). In turn, if firms innovate, then they are more likely to use IPRs ($H5$). And if they use them, then they also tend to have fewer competitors ($H6$). Apart from the vector of general control variables, this set of assumptions and hypotheses provides a full description of the core model.

3 Data

The data are from seven waves of the *Swiss Innovation Survey* (SIS) conducted by the Swiss Economic Institute (KOF) at the ETH Zürich between 1999 and 2015.[3] Observations come from a stratified random sample of firms with at least five employees in manufacturing, construction, and service sectors. The stratification covers 28 industries and three size classes. The firm panel is unbalanced, but pooling provides a sample of ca. 10'900 observations.[4]

Table 1 explains all the variables used. Among the endogenous variables, *competition* is measured by the self-reported number of principal competitors in the firm's main product category worldwide. These had to fall into either of four mutually exclusive classes. Similarly, *R&D effort*, *innovation* outcome and *IPR use* are all ordinal variables. Among the vector of general control variables, we include, e.g., the technological potential, human capital, foreign ownership, export status, firm size, firm age as well as time and industry dummies.

The exclusionary restrictions fall into two groups. First, we apply sectoral taxonomies that characterize the technological regime in which firms operate. They were built from European CIS micro-data at the Eurostat safe centre (Peneder 2010). Statistical clustering algorithms were applied to the standardized distributions of heterogenous firm types. One is the typical sector distribution of *opportunity conditions*, another the *cumulativeness of knowledge* (reflecting the relative importance of external vs. internal knowledge for innovative firms). Finally, the sector-level *appropriability conditions* were clustered from differences in the distribution of EU firms applying IPRs to protect their innovations. The taxonomies are strictly exogenous: first, because firms are too small for any plausible incidence of reverse causality; second, the Swiss firms studied here were not included in the EU micro-data.

The second set of exclusionary restrictions refer to self-reported characteristics that we assume to be unaffected by the endogenous variables. Among them we use the general growth of demand for the firm's primary product, the perceived effectiveness of IPRs, and a latent variable called hampering factors (which comprises various self-reported barriers to innovation).

[3]The surveys are available from www.kof.ethz.ch.

[4]Despite the available data panel, we do not apply lagged variables for three reasons. First, we have no information on the accurate timing of events, e.g., for R&D inputs to yield successful innovations, or of innovations to affect the number of competitors. Second, the ordinal nature of most endogenous variables provides only little variation over time. Finally, we would loose many observations, since the panel is highly unbalanced.

Table 1: Definition of variables

Symbol	Variable	Definition
		Endogenous Variables These are part of the endogenous system and mutually influence one another.
E_i	R&D effort	1 ... intramural R&D = 0 2 ...< R&D < 1.5% of total sales 3 ... 1.5% < R&D ≤ 5% 4 ... R&D > 5% of total sales
I_i	Innovation	1... Adaptive 1: pursuing opportunities other than from technological innovation (Non-innovators) 2...Adaptive 2: introducing new products and/or processes new to their firm but not new to the market (Technology adopters) 3...Creative 1: product/process innovator (new to the firm) developing innovation mostly on their own 4...Creative 2: introducing products new to the market
C_i	Competition	Number of principal competitors in the main product market worldwide; subjective firm assessment according to the following ordinal scale: 1 ... Number of principal competitors ≤ 5 2 ... Number of principal competitors > 5 & ≤ 15 3 ... Number of principal competitors > 15 & ≤ 50 4 ... Number of principal competitors > 50
P_i	IPR use	Non-linear binary combination of IP rights usage: $ln[(\text{patents}+\text{copyrights}+\text{trademarks}+\text{designs})^2+1]$
		Firm-level Exclusion Restrictions These are particular to a given equation in the system, but are not appropriate in all equations for theoretical reasons.
h_i	Hampering factors	Score of self-reported factors hampering innovation (or survey selection effect)
p_i^e	IPR effectiveness	Effectiveness of protection[5] of innovation-based competitive advantages (Likert 1-5)
d_i^p	Past demand	Past demand in primary market (Likert 1-5)
d_i^e	Expected demand	Expected demand in primary market (Likert 1-5)
		Sector-level Exclusion Restrictions The sectors are classified according to a characteristically high share of firms in Europe (other than Switzerland) with trait.
$\tilde{O}_s$	Opportunity	1... neither intramural nor external R&D activities 2... acquisition of external R&D, machinery, rights, etc. 3... own R&D, but less or equal 5% of total sales 4...own R&D, more than 5% of total sales
$\tilde{A}_s$	Appropriability	1... no appropriation measures 2... appropriation only by secrecy, lead-time, or complexity of design 3... appropriation by design patterns, trademarks, or copyright (with or without strategic methods) 4... appropriation by patents (alone or with either strategic or other formal methods) 5... appropriation by patents together with other formal and strategic methods
$\tilde{K}_s$	Cumulativeness	1... reporting neither internal nor external knowledge sources of high importance 2... creative firms with internal sources less important than external sources; adaptive firms with internal sources more or equally important 3 ... creative firms with internal sources more or equally important than external sources; adaptive firms with external sources more important
		Control Variables
$\mathbf{X}[i,0]$	Tech potential	Technological potential (Likert 1-5)
$\mathbf{X}[i,1]$	Higher education	Share of employees with higher education
$\mathbf{X}[i,2]$	Foreign owned	Whether the firm is owned by a non-Swiss entity
$\mathbf{X}[i,3]$	Export share	Share of firm sales coming from exports
$\mathbf{X}[i,4]$	Age	Firm age in years
$\mathbf{X}[i,5]$	Size	Firm size in number of full time employees
$\mathbf{X}[i,6]$	Intercept	Level of null model

4 Econometric model

The econometric model consists of four equations, which we estimate by 3SLS and using extra-sample industry variation together with firm-level variables without causal parents for identification. First, the *innovation opportunity* function specifies for firm i how the self-reported number of competitors C_i affects the firm's R&D effort E_i. Testing for the inverted-U relationship, we add a nonlinear term and expect a positive sign for γ, and γ^{sq} to be negative. The exclusion restriction $\tilde{O}_s$ is a sectoral taxonomy of "opportunity conditions". It affects the likelihood that an individual firm invests in R&D, whereas its impact on the innovation outcome is only indirect, i.e. through variation in E_i.

$\tilde{O}_s$ is therefore not correlated with the error term in the following *innovation production* function, which predicts the probability of innovation success I_i. For the exclusion restriction, we employ a sectoral taxonomy of the "cumulativeness of knowledge" K_s. It accounts for whether increasing returns to knowledge creation affect the firm's probability of innovation. Only if successful, can it affect the use of IPRs P_i or the degree of competition C_i.

In both the *innovation appropriability* function and the *innovation impact* function is K_s therefore uncorrelated with the error terms. Both functions apply sectoral appropriability conditions $\tilde{A}_s$, also derived from the EU-CIS, as the main exclusion restriction. For the IPR equation, we additionally use the firm's perception of their principal effectiveness e_i. Finally, $\tilde{A}_s$ affects innovation incentives only indirectly, that is if they have an influence on C_i. Consequently, it is uncorrelated with the error term in the innovation opportunity function. The same applies to population density and regulatory quality, which we assume to have a positive impact on competition, but exclude from the estimation of Equation (1).

This closes the system, which we can summarise as follows:

$$\begin{pmatrix} E_i \\ I_i \\ P_i \\ C_i \end{pmatrix} = \left(\begin{array}{c|c|c|c} \gamma_1 C_i + \gamma_1^{sq} C_i^2 & +\tilde{\omega}_1 \tilde{O}_s + \tilde{\kappa}_1 \tilde{K}_s & +\epsilon_2 e_i + \delta_1^p d_i^p + \delta_1^e d_i^e & +\boldsymbol{\chi}_1 \mathbf{X}_{1,i} + \upsilon_{1,i} \\ \epsilon_2 E_i & +\tilde{\kappa}_2 \tilde{K}_s & & +\boldsymbol{\chi}_2 \mathbf{X}_{2,i} + \upsilon_{2,i} \\ \iota_3 I_i & +\epsilon_3 e_i + \tilde{\alpha}_3 \tilde{A}_s & +\delta_3^e d_i^e & +\boldsymbol{\chi}_3 \mathbf{X}_{3,i} + \upsilon_{3,i} \\ \iota_4 I_i + \epsilon_4 P_i & +\delta_4^p d_i^p + \tilde{\alpha}_4 \tilde{A}_s & +\delta_4^e d_i^e & +\boldsymbol{\chi}_4 \mathbf{X}_{4,i} + \upsilon_{4,i} \end{array} \right) \quad (1)$$

On the right hand side, the variables in the first column represent the endogenous explanatory variables, followed by exclusion restrictions at the sector- and firm-level, respectively. $\mathbf{X}_i$ represents a vector of control variables and υ_i the error terms.

5 Findings and conclusions

Table 2 reports the detailed results for all four equations. To begin with the basic relationships, the estimates confirm the inverted-U shaped impact of competition on R&D effort (assumption $A1$) in the first equation. Higher growth of demand, better opportunity conditions and technological potential, university graduates and exports associate with a higher R&D effort. Interestingly, the perceived effectiveness of IPRs has no significant influence, which amounts to rejecting hypothesis $H4$. In the second equation, R&D effort buys a greater probability of successful innovation ($A2$). In addition, firm size and a high technology potential raise the probability of success, while for the average firm it decreases with the cumulativeness of knowledge. In equation four, innovation reduces competition ($A3$). So does foreign ownership, whereas demand growth, technology potential, higher education, exports, age and size associate with a larger number of competitors.

Turning to the use of IPRs in equation 3, successful innovation is a necessary precondition ($H5$), while firms that operate in industries with favourable appropriability conditions ($H1$) and those which perceive IPRs to be effective ($H3$), are more likely to use them. A higher expected growth of demand, technology potential, more employees with higher education, exports and firm size are further conducive factors. In contrast, foreign ownership tends to obstruct it. Finally, our main interest culminates in the impact of IPRs on competition, where the findings reward our attention to both the sector and firm level variation. Consistent with hypothesis $H2$, better appropriability conditions at the sector level tend to increase the number of competitors, while the firm's own use of IPRs is a means to reduce it ($H6$).

Instrumental variable tests conducted by 2SLS estimations for each pair of equations with a causal connection confirm that all of them are correlated with the endogenous variable (rejecting the Anderson canonical correlation test for under-identification), while the fact that they are predetermined guarantees (by assumption) that they are uncorrelated with the error terms (Table 3). Also the Sargan tests confirm that no equation is over-identified.

To conclude, simultaneously solving for IPR use, competition and innovation helps to resolve some of the ambiguity associated with the (anti-)competitive effect of IPRs. And the distinction between industry and firm-level effects is of particular importance:

- At the industry level, better *appropriability conditions* significantly raise the number of competitors, presumably by allowing a plethora of tiny walled gardens where firms can protect their innovation temporarily.

- This is different from the impact of individual choices for a given industry structure, where the firm's actual *use of IPRs* significantly reduces the number of competitors for its principal product.

- Confirming an inverted-U relationship, the endogenous system implies that fewer competitors tend to increase R&D, if initial competition is strong; and to reduce it, if initial competition is weak.

The final impact of IPRs on innovation hence depends on a non-linear second order effect of decreasing competition on the firm's innovation behavior. Consequently, IP regulations may require closer integration with competition policy.

Table 2: Full 3SLS System

Variables	R&D effort	Innovation	IPR use	Competition
Endogenous System				
Competition	11.2***			
	(3.57)			
Competition^2	-2.18***			
	(-3.59)			
R&D effort		0.306***		
		(9.60)		
Innovation			0.487**	-36.8***
			(3.13)	(-28.0)
IPR use				-3.10***
				(-4.91)
Firm-level exclusion restrictions				
Hampering Factors	0.011			
	(0.73)			
IPR effectiveness	0.005		0.091***	
	(-0.29)		(1.16)	
Past Demand	0.074***			0.294***
	(2.99)			(6.28)
Expected Demand	0.091***		0.030***	1.28***
	4.01		2.62	(12.9)
Sector-level exclusion restrictions				
Opportunity	0.435***			
	(2.47)			
Cumulativeness	-0.147	-0.026***		
	(-1.113)	(-3.60)		
Appropriability			0.063***	0.824***
			(4.37)	(6.02)
Control variables				
Tech Potential	0.066***	0.022***	0.029***	2.04***
	(3.92)	3.19	2.83	(12.5)
High education	0.008***	-0.000	0.002***	0.078***
	(7.11)	(-0.797)	3.93	(8.514)
Foreign owned	-0.119	0.005	-0.067***	-2.34***
	(-2.17)	(0.820)	(-2.86)	(-5.15)
Export share	0.008***	-0.000	0.005***	0.076***
	(9.54)	(-1.46)	15.5	(9.95)
ln(Age)	0.024	0.011	0.017	0.564***
	(1.01)	(1.04)	(1.39)	(2.36)
ln(Size)	0.017	0.041***	0.078***	2.82***
	(0.69)	(6.62)	(6.37)	(15.6)
Intercept	-11.9***	0.838***	-1.40	30.9***
	(-3.45)	(14.9)	(-9.99)	(20.1)

Note: N=10'967; (t-stat); *10%,** 5%,*** 1%. Industry and year dummies omitted for concision.

Table 3: Summary of IV test statistics

Endogenous variable	Under- Anderson L-M (p)	Weak identification Cragg-Donald Wald (F)	Over- Sargan (p)
R&D effort	0.009***	3.10	0.960
Innovation	0.017**	3.78	0.345
IPR use	0.009***	4.73	0.371
Competition	0.000***	4.90	0.113

*0.10, **0.05,***0.01; stars for C-D test represent relative bias of S-Y critical values.

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