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Contract Enforcement and R&D Investment

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Contract Enforcement and R&D Investment

Michael Seitz and Martin Watzinger*

February 2013

Abstract:
In this article we study the relation between the quality of contract enforcement and R&D investment across countries and industries. If companies invest successfully in R&D they are open for exploitation by their supplier if supply contracts are not enforceable. This hold-up problem can reduce the incentive to invest in R&D ex-ante. In line with this theoretical idea we find in the empirical analysis that R&D investment increases with the quality of the judicial system. This effect is particularly strong in industries which rely more on contracts to acquire input and in which it is harder to vertically integrate.

Keywords: R&D Investment, Contract Enforcement, Institutions
JEL Classification Numbers : O30, O43, P48

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1 Introduction

It is well known that there are large and persistent differences in productivity levels of companies across countries. An obvious reason is that that some companies in some countries invest more in Research & Development of new products than others: For example, companies in Italy in 2010 invested around 0.67% of Italy's GDP, while the corresponding number for Germany is 1.90% (Eurostat 2012). But why do Italian firms invest so little? Which factors determine R&D spending of companies across countries? In this study we examine how much of the cross country variation in R&D investment can be explained by the differences of contracting institutions. The channel we consider builds on the insight that if contracting institutions are weak, companies which invest in the development of new products potentially face exploitation by their supplier - in particular if they are bound to their supplier by relationship-specific investments. The threat of exploitation might then lead ex-ante to underinvestment in R&D (Grossman and Hart 1986, Hart and Moore 1990, Acemoglu, Antras, and Helpman 2007).

To study whether contracting institutions influence R&D spending, we test if countries with better contract enforcement have a relatively higher R&D intensity in industries for which relationship-specific investments are more important. To quantify the importance of relationship-specific investment in an industry, we measure the proportion of inputs which cannot be bought or sold on an organized exchange. On an exchange with many buyers and sellers, the hold-up potential is limited. In contrast if an input is customer specific and therefore not traded in thick markets, the value of the input might be higher within the buyer-seller relationship than outside of it. If the proportions of input procured through such individualized contracts is large, the industry is susceptible to hold-ups and defined as "contract intensive". As primary measure for the quality of the contracting environment we use the "rule of law" index from Kaufmann, Kraay, and Mastruzzi (2007).

In our empirical analysis we find that an industry's R&D intensity is indeed positively related with the quality of contract institutions on the country-level and this effect is most pronounced in industries which are more contract intensive. To give

a feeling for the magnitude of the effect, consider the examples of Italy and Germany. If Italy were to improve the quality of its judicial system to the level of Germany, then, according to our estimates, R&D investments in the highly contract-intensive motor-vehicle industry would increase by 0.64 percentage points or US $ 300 Million. In contrast, in the low-contract intensive industry producing food products, the R&D intensity would only increase by 0.08 percentage points, or about US $ 3 Million. In general, the effect is stronger in countries with a weaker rule of law and in industries in which it is more difficult to forward integrate.

To mitigate concerns regarding the robustness of the analysis, we have included a wide range of control variables and alternative measures for the dependent and independent variables. We obtain similar results if we use instead of R&D intensity the absolute levels of R&D investments, patent counts and patent citations as dependent variable. Controlling for other potential determinants of R&D investments such as human or physical capital, intra-industry trade, productivity growth or financial development does not change our results. Instead of the "rule of law" index we can also use alternative measures for the overall quality of the judicial system, such as the enforceability of contracts or the risk of contract repudiation and get similar consistent results. To account for omitted variable bias and a potential reverse causality regarding the overall quality of the judicial system, we use legal origin as an instrument for rule of law. The resulting coefficients and an additional sensitivity analysis support the qualitative and quantitative conclusion from the OLS estimates.

This study is the first to empirically examine how institutions promote R&D investments and can thereby helps to explain observed differences in economic development across countries and industries. Thus it contributes to the large and growing literature on the determinants of R&D investment and to the literature on the economic effects of legal institutions. Financial development, taxes, subsidies and intellectual property rights protection are major determinants for R&D investment (Carlin and Mayer 2003, Bond, Harhoff, and Reenen 2010, Brown, Fazzari, and Petersen 2009, Maskus, Neumann, and Seidel 2011, Hines 1995, Bloom, Griffith, and Reenen 2002, Zhao 2006) and several studies find that a better contracting

environment is associated with a higher level growth, exports, product quality, comparative advantage or trade (Castro, Clementi, and MacDonald 2004, Acemoglu, Johnson, and Robinson 2004, Acemoglu, Aghion, Griffith, and Zilibotti 2010, Azim and Fujiwara 2010, Levchenko 2007, Costinot 2009, Nunn 2007). Yet, none of these studies considers empirically the effects of legal institutions on R&D investment.

A second strand of literature related to our study focuses on the effect of hold-up problems on different kinds of investments. Since the seminal work by Hart and Moore (1988), a large theoretical literature suggested contractual solutions to the underinvestment problem (MacLeod and Malcomson 1993, Noldeke and Schmidt 1995, Edlin and Reichelstein 1996) while a burgeoning empirical literature tested for measureable implications of incomplete contracts. Most of these studies focus on a single industry such as trucking (Baker and Hubbard 2003, Baker and Hubbard 2004), defense (Crocker and Reynolds 1993), footwear (Woodruff 2002) or housing (Field 2005, Field 2007, Gebhardt 2011), while our study uses cross industry variation. A related literature studies the effect of property rights on investment decisions in developing countries, such as Besley (1995) and Jacoby and Mansuri (2008). They find that improving property rights in developing countries can help to increase investments, yet they do not consider R&D.

The rest of the paper is structured as follows: in section 2, we spell out a theory of imperfect contracting and R&D. Section 3 describes the dataset as well as the definition and construction of our key variables of interests. Section 2 explains the empirical model and identification strategy employed in the subsequent analysis. In section 4, we present the results of our baseline specification, robustness checks and instrumental variables regressions. Section 5 concludes.

2 Theoretical & Empirical Framework

In this section we model the impact of imperfect contract enforcement on R&D investment in a supplier-producer relationship. To focus on the effect of contract enforcement problems we abstract from a number of important features of the R&D process such as uncertainty and spillovers.

Model Set-Up

Consider the following simple game between a representative risk-neutral supplier S and a risk-neutral manufacturer M. The manufacturer can develop an innovative product of value r by investing r units in R&D with costs $c(r)$. The cost function is strictly increasing, convex and differentiable and satisfies the Inada conditions. The manufacturer needs n inputs to build the product and each input contributes equally to its value. This means leaving out one input reduces the value of the good to $\frac{n-1}{n} \cdot r$. The fraction $(1-\alpha)$ of the required inputs can be bought on the open market, while the fraction α can only be bought from the supplier S. The supplier can produce these inputs at no cost. The inputs of the supplier are specific in the sense that the only possible customer for the supplier is the manufacturer and the only possible source of the input is the supplier. Prices are assumed to be non-negative .

We consider the following game-structure:

1. The manufacturer offers the supplier a contract which implies that the supplier delivers the input and receives a price p.
2. The supplier decides whether to accept or reject the contract.
3. After signing the contract, the manufacturer invests in R&D.
4. After investment, the manufacturer wants to build the final product.
   (a) With a probability of γ the contract is enforced and the manufacturer gets the input product for price p.
   (b) With a probability of $1-\gamma$, the contract is not enforced. If this is the case, both parties engage in symmetric Nash bargaining over the price. The outside option for the manufacturer is the value of the product without the inputs of the supplier, $(1-\alpha) \cdot r$, while the outside value of the supplier is zero.
5. Transaction takes place and the producer manufactures and sells the final good.

In our game, the contract enforcement is imperfect, because the manufacturer cannot be sure that the input is delivered for the specified price. One reason for such an incompleteness might be the failure of the courts to enforce the delivery or procedural complexity, making contract enforcement unfeasible. Thus we interpret γ as a measure of the quality and predictability of contract enforcement.

Equilibrium

In the following we characterize the sub-game perfect equilibrium by backward induction. In the last step, the product is always produced and sold on the market. In Step (4), there are two cases to consider, one in which the contract is enforced and one in which the contract is not enforced. Given the contract is enforced, the supplier gets the specified price p and delivers the inputs. The manufacturer then makes a profit of

$$\pi_m^{enforced} = r - c(r) - p.$$

In contrast, if the contract is not enforced, the manufacturer and the supplier engage in symmetric Nash bargaining over the price and the outside option of manufacturer is the value of product without the inputs, $(1-\alpha)\cdot r$, while the outside option of the supplier is zero.

As a result of this bargaining the manufacturer and supplier agree to exchange the input for

$$\hat{p} = \frac{\alpha}{2} \cdot r$$

and the resulting profit for the manufacturer is

$$\pi_m^{\text{not enforced}} = r - c(r) - \hat{p}.$$

Anticipating this development, the producer invests in Step (3) in R&D to maximize the following profit function:

$$\pi_m = \gamma \cdot \pi_m^{upheld} + (1-\gamma) \cdot \pi_m^{invalid} = \gamma \cdot [r - c(r) - p] + (1-\gamma) \cdot \left[r - c(r) - \frac{\alpha}{2} \cdot r \right].$$

The resulting optimal R&D investment is then characterized by

$$c'(r^*) = 1 - \frac{\alpha}{2} + \gamma \cdot \frac{\alpha}{2} \tag{1}$$

Given that the marginal cost function $c(r^*)$ is strictly increasing and convex,

$$\frac{\partial r}{\partial \alpha} = -\frac{\frac{1}{2}(1-\gamma)}{c''(r)} < 0 \tag{2}$$

from the implicit function theorem. Therefore the optimal amount of R&D investment is higher if the fraction of inputs which have to be acquired on the market (α) is lower. Furthermore, as

$$\frac{\partial^2 r}{\partial \gamma \partial \alpha} = \frac{1}{c''(r)} > 0, \tag{3}$$

a better contract enforcement lead to more investment in R&D in particular in industries which depend on relationship specific inputs.

In step (2) the supplier decides to accept every contract with an expected profit weakly larger than zero, i.e.

$$\pi_s = \gamma \cdot p + (1-\gamma) \cdot \frac{\alpha}{2} \cdot r \geq 0.$$

This implies that in the first step the producer offers the supplier a price of zero, $p = 0$.

Empirical Strategy & Predictions

To derive an empirical testable specification, we assume that $c'(\cdot)$ in Equation 1 can be approximated with a linear function in R&D expenditures and that there are other observable and unobservable characteristics (ε) which also influence the marginal costs of R&D. The observable characteristics are year- , industry- and country dummies as well as control variables (x). We furthermore assume that the contract intensity measure is industry specific and time-invariant. Given all these assumptions the equation we estimate at the country-industry-year level is then

$$r^*_{ict} = \varphi_0 + \varphi_1 \cdot \alpha_i + \varphi_2 \cdot \gamma_{ct} \cdot \alpha_i + \varphi_x \cdot x + \eta_c + \eta_i + \eta_t + \varepsilon. \tag{4}$$

where i indicates the industry, c is the country and t is the year.

According to Equation (2) and (3), a more contract intensive industry should have a lower R&D spending ($\varphi_1 < 0$) and φ_2 should be positive, i.e. that countries with better contract enforcement institutions have more R&D spending and this effect is particularly large in contract intensive industries. Unfortunately, φ_1 is only identified from cross-industry variation and therefore cannot be estimated if there is some industry specific component in marginal cost function of R&D, i.e. controlling for industry fixed effects.

As it seems quite likely, that the marginal costs of R&D differ from industry to industry and because we are mainly interested in the influence of rule of law through contracts, we concentrate in the empirical analysis on the estimation of the influence of the rule of law-interaction, i.e. φ_2. This parameter is identified from the combination of cross-industry variation in bargaining power and cross-country variation in the quality of contract enforcement. This identification strategy was first proposed by Rajan and Zingales (1998) and has been used in numerous studies (e.g. Nunn 2007, Manova 2009, Pang and Wu 2009). In combination with R&D intensities the approach has been used by Maskus, Neumann, and Seidel (2011) to estimate the influence of financial development.

Yet, identification can fail for several reasons: First, we might omit some factors which are causal for the marginal costs of R&D or the demand for R&D and correlated either with the quality of contract enforcement or contract intensity. For example, countries with a better rule of law (or more contract intensive industries) might be closer to the technological frontier which potentially changes the marginal costs of R&D. To address this problem we control for a large vector of control variables. Second, there might be reverse causality from R&D intensities to legal institutions. It is quite possible that companies which conduct a lot of research influence the political process to improve the legal contracting environment. To investigate this threat of identification, we use the legal origin of a country to isolate variation in rule of law which is orthogonal to contemporary R&D investments (Nunn 2007).

3 Data

In order to test our predictions we collect data different measures for R&D expenditures and the quality of contract enforcement from standard sources. To approximate the percentage of inputs which cannot be bought or sold on the market we construct a measure following the methodology of Nunn (2007). We describe our data sources in turn.

R&D Expenditures

For our main specification we use R&D intensity as dependent variable. To construct this measure we use R&D expenditures from the STAN database of the OECD, which contains R&D expenditures and production data for several countries and industries. The industries are classified according to the two-digit ISIC Revision 3.1. The data is available for the period of 1987 to 2007 for 40 countries and 28 industries. Due to many missing values we focus only on OECD countries and the manufacturing sector, restricting the sample to 23 countries and 21 industries from 1995 to 2005.

As alternative dependent variables we use patent count data on the country-industry level from Eurostat and R&D expenditures from the Compustat Global firm level dataset. We use all firms with non-missing values for R&D expenditure and sales. In total we arrive at an unbalanced panel of 3927 companies in 91 industries and 43 countries. We match these companies with data on patent per company and patent cites from NBER U.S. Patent Citations Data File (Hall, Jaffe, and Trajtenberg 2001) to arrive at two additional outcome measures.

Contract Enforcement

In our main specification we as measure for the quality of contract enforcement the "rule of law index" developed by Kaufmann, Kraay, and Mastruzzi (2007) which is based on governance indicators of the World Bank. This index comprises a number of different variables measuring the perceptions of the predictability, competence and effectiveness of the judicial system within a country. It has been widely used in the literature to measure the judicial quality of a country (e.g. Nunn 2007, Levchenko

2007, Berkowitz, Moenius, and Pistor 2006). The index ranges from 0 to 10, with 0 indicating a bad and 10 a good judicial system.[1] Data is available for 1995 to 2005 for all countries in the sample.[2] In the robustness section, we use nine alternative measures for the judicial quality of a country taken from Porta, de Silanes, Shleifer, and Vishny (1998), Djankov, Porta, Lopez-De-Silanes, and Shleifer (2003) and Park (2008). Each variable is described in detail in Table 1.

Table 2 reports means for the rule of law index, R&D Intensities and factor endowments for the year 2005.

Contract Intensity

For each industry we construct a "contract intensity" measure by calculating the percentage of input which cannot be bought or sold on an organized exchange and therefore has to be sourced by contracts. To do this, we use in a first step the 2002 United States Input-Output (I-O) Use Table from the Bureau of Economic Analysis (BEA 2011). This table provides information on the share of intermediate inputs used to produce a final good in 439 industries. In a second step, we combine this information with data on whether these intermediate inputs are bought or sold through an organized exchange or reference priced, using data by Rauch (1999).[3] Combining these two data sources allows us to calculate the share of each intermediate input used in the production that is neither reference priced nor sold on an organized exchange. In a last step we aggregate the final goods of the United States I-O Use Table to the two-digit ISIC Rev. 3.1 level of the OECD data on R&D investments. Table 3 lists the means of the constructed measure for each industry.

In the robustness section, we use four alternative measures for the contract intensity of an industry: First, a company might not only be exploited by its supplier but also by its customer. Therefore we use also the percentage of outputs which are not

[1] The original index ranges from -2.5 to 2.5. For convenience we transform the index to range from 0 to 10.

[2] Due to missing values for the years 1997, 1999 and 2001 we use a non-parametric linear interpolation to estimate these values. Given the high persistency of institutions this procedure does not affect our results.

[3] Rauch (1999) classifies 1,190 goods into three different categories: sold on an organized exchange, reference priced or neither.

Table 1: Alternative Measure for Rule of Law

Measure	Description	Range
	Source: Djankov et al. (2003)	
Formalism index	The index measures substantive and procedural statutory intervention in judicial cases at lower-level civil trial courts. For example if there are professional judges, a written argument is necessary, mandatory time limits or a superior review of judgements.	0-7 (higher: higher intervention)
Legal system is...		
...consistent	"In resolving business disputes, do you believe your country's court system to be consistent?"	1-6 (higher: more consistency)
...uncorrupt	"In resolving business disputes, do you believe your country's court system to be honest/uncorrupt?"	1-6 (higher: less corrupt)
...fair and impartial	"In resolving business disputes, do you believe your country's court system to be fair and impartial?"	1-6 (higher: more impartial)
Enforceability of contracts	The relative degree to which contractual agreements are honored and complications presented by language and mentality differences.	0-10 (higher: higher enforceability)
Law and Order	Integrity of legal system in 2000. This component is based on the Political Risk Component 1 (Law and Order) from the PRS Groups International Country Risk Guide (various issues).	Rankings are modified to a ten-point scale.
	Source La Porta et al. (1998)	
Measure	Description	Range
Risk of expropriation	ICR's assessment of the risk of "outright confiscation" or "forced nationalization". Average of the months of April and October of the monthly index between 1982 and 1995.	0-10 (higher: less risk)
Repudiation of contracts by government	ICR's assessment of the "risk of a modification in a contract taking the form of a repudiation, postponement, or scaling down" due to "budget cutbacks, indigenization pressure, a change in government, or a change in government economic and social priorities." Average of the months of April and October of the monthly index between 1982 and 1995.	0-10 (higher: less risk)
	Other Sources	
Measure	Description	Range
Index of Patent Protection	This index published in Park (2008) provides an indicator of the strength of patent protection in a country. The index is the unweighted sum of five separate scores for: coverage; membership in international treaties; duration of protection; enforcement mechanisms; and restrictions.	0-5 (higher: better protection)
Political Stability	The indicator "Political Stability and Absence of Violence Government" from Political Risk Services is an aggregate indicator for Internal and External conflict and Ethnic tension. The data is available from the World Bank website.	0-10 (higher: more stability)

Table 2: Country Characteristics

	Rule of Law	R&D Int.	Human Cap.	Physical Cap.
Austria	8.63	2.16	2.23	71628
Belgium	7.62	2.13	2.77	76452
Canada	8.33	2.39	3.01	82443
Czech Republic	6.71	0.57	.	.
Denmark	8.67	2.97	3.00	70515
Finland	8.78	2.30	2.83	89196
France	7.80	2.47	2.20	84929
Germany	8.21	2.48	2.66	89368
Hungary	6.87	0.26	3.09	33857
Iceland	8.52	2.24	2.53	66643
Italy	7.40	0.94	2.15	82318
Japan	7.63	4.75	2.64	64181
Korea	6.71	1.06	2.52	24651
Netherlands	8.43	3.01	2.66	79069
New Zealand	8.68	0.13	3.37	78048
Norway	8.76	2.38	3.01	94831
Poland	6.41	0.31	2.63	33949
Portugal	7.49	0.36	1.67	29437
Slovak Republic	5.84	0.26	.	.
Spain	7.52	0.91	2.00	61638
Sweden	8.56	4.32	2.83	72777
Switzerland	8.77	7.95	2.76	107870
United Kingdom	8.30	2.83	2.68	50409

Notes: The table reports the means of the rule of law index, R&D intensities, physical and human capital across countries.

Table 3: Industry Characteristics

	Contract Int.	R&D Int.	Human Cap. Int.	Physical Cap. Int.
Basic metals	0.25	0.51	0.31	1.22
Chemical products	0.26	3.95	0.54	0.76
Communication	0.91	6.58	0.62	1.20
Electrical machinery	0.58	2.36	0.54	0.66
Fabricated metal	0.43	0.53	0.38	0.76
Food prod	0.16	0.20	0.36	0.84
Leather products	0.55	0.49	0.36	0.79
Machinery	0.72	1.82	0.39	0.82
Medical instruments	0.69	4.87	0.68	0.52
Motor vehicles	0.70	1.94	0.27	0.84
Non-metallic products	0.35	0.53	0.30	0.94
Office machinery	0.79	5.92	0.75	0.79
Other transport	0.58	3.38	0.52	0.55
Paper products	0.50	0.34	0.34	1.13
Petroleum products	0.07	0.35	0.36	1.75
Plastics	0.29	0.98	0.32	0.93
Printing	0.74	0.13	0.41	0.65
Textiles	0.46	0.52	0.39	0.75
Tobacco products	0.20	0.36	0.37	0.22
Wearing apparel	0.28	0.25	0.36	0.45
Wood products	0.45	0.15	0.32	0.66

Note: This table reports the means of our contract intensity measure, physical capital intensity and human capital intensity across industries.

sold on an organized exchange as a measure ("Forward weights"). Second, we include reference priced goods as inputs which are not sourced by contracts ("Contract Int. v2"). Third, we use 1 minus an Herfindahl index of the concentration of intermediate inputs used in production as an alternative proxy for the susceptibility of hold-up of an industry (Blanchard and Kremer 1997, Levchenko 2007). The idea is, that it is easier to vertically integrate if there are just a few input supplier. Lastly we follow Acemoglu, Johnson, and Mitton (2009) by using capital intensity as a proxy for the degree of holdup problems within an industries.

Control Variables

We use various control variables which might be causal for R&D investment and which might be correlated with either contract enforcement in a country or contract

intensity in an industry. All these variables are from standard sources. For example human and physical capital accumulation available in a country might be caused by a good rule of law. Likewise the human and physical capital intensity of an industry might be correlated with contract intensity. In our estimation we use the interaction of capital and capital intensity to construct measure for capital usage in a specific country and industry.

Data on factor endowments for each country and factor intensities for every industry are from standard sources. We use the (log) stock of physical capital per worker and (log) human capital per worker as constructed by Caselli (2005). Human capital per worker is defined as the average years of schooling in the population over 25 years old and physical capital is the average capital stock per worker in a country. Data on factor intensity and value added stem from Bartelsman and Gray (1996). Capital intensity is measured as the ratio of total real capital stock and value added for industries in the United States and human capital intensity is calculated as non-production worker wages divided by the total wages for United States industries.

Other control variables are TFP growth from the UNIDO database (UNIDO 2005), Intra-Industry Trade is derived from the Grubel index of Feenstra, Lipsey, Deng, Ma, and Mo (2005) and Input Variety is measured as one minus the Herfindahl Indux of Input shares from BEA data (BEA 2011). Value added, income (measured by GDP per capita) and total bank credit divided by GDP is taken from the OECD databases. Summary statistics for all employed variables are given in Table 4.

4 Results

Descriptive Evidence

Before turning to the estimation results, we examine the raw data whether the quality of contract enforcement is indeed important for R&D investments. To do this, we plot in Figure 1, R&D intensities across countries against different measures for rule of law across countries for the year 2005. According to this figure, there is a positive correlation between R&D and each of the different measures. In addition, the influence of rule of law seems to be stronger in contract-intensive industries: For

Table 4: Summary Statistics

	mean	sd	min	max	p10	p90
R&D Intensity	1.86	3.73	0.00	72.55	0.03	5.39
Rule of Law	7.72	0.85	5.60	8.92	6.62	8.72
Human Capital	0.98	0.14	0.59	1.20	0.80	1.16
Physical Capital in Thsd. USD	0.01	0.00	0.01	0.01	0.01	0.01
Contract Intensity	0.49	0.22	0.07	0.91	0.20	0.79
Human Capital Int.	0.43	0.14	0.26	0.80	0.30	0.66
Physical Capital Int.	0.83	0.34	0.16	2.34	0.50	1.19
Income per Capita	9.97	0.38	8.85	10.90	9.37	10.35
Value Added in Billion. USD	6.62	11.52	-0.05	110.79	0.21	16.59
Intra-Industry Trade	0.67	0.23	0.07	1.00	0.29	0.94
TFP growth	0.00	0.04	-0.13	0.26	-0.04	0.04
Credit/GDP	0.67	0.29	0.20	1.66	0.21	1.10
Input Variety	0.96	0.06	0.00	0.99	0.87	0.99
Observations	4634					

Panel (a) of Figure 2 we split the sample of countries at the median of rule of law in 2005. Then we plot the difference in R&D intensities for these two groups for different industries ordered by their contract intensity. Each industry is labeled with its two digit SIC code. In Panel (b) we repeat the exercise for Germany (rule of law index of 8.23) and Italy (rule of law of 7.22). In both panels the difference in research intensity between the countries with a high rule of law index and a low rule of law index increases with the contract intensity of the industry. For example, in the upper right corner, in industry 32 ("Radio television and communication equipment") the difference is much larger than in industry 23 ("Coke and refined petroleum products").

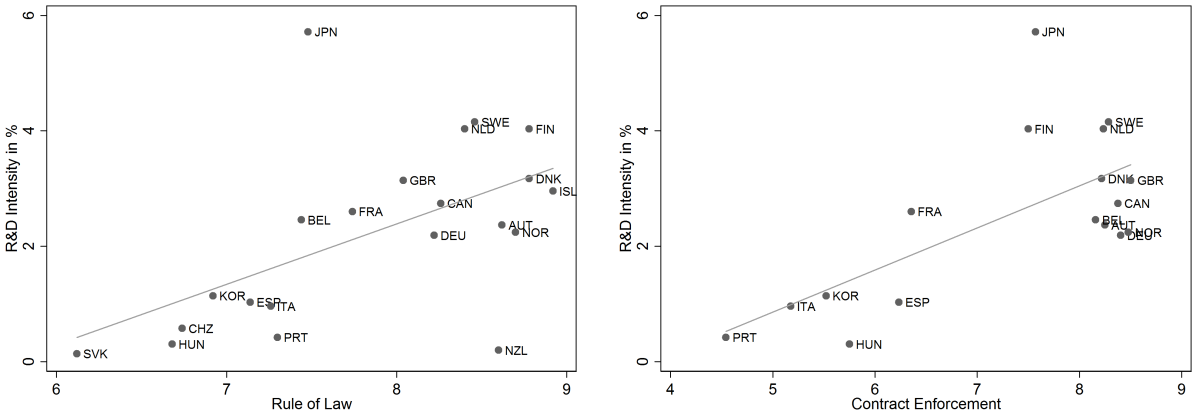
Estimation Results

Now turning to our regression results, Table 5 reports the results from estimating equation (4). The dependent variable in all specifications is the R&D intensity, i.e. R&D expenditure in an industry divided by production. Throughout the study, we use multi-way clustering on country and industry level to account for a rather general forms of within-group correlation. The sample consists of 23 countries and 21 manufacturing industries for the years 1995 to 2005. Therefore, the maximum number of possible observations is 4,830. However, because data on R&D investments and

Figure 1: Descriptive Evidence: R&D and different measures for rule of law

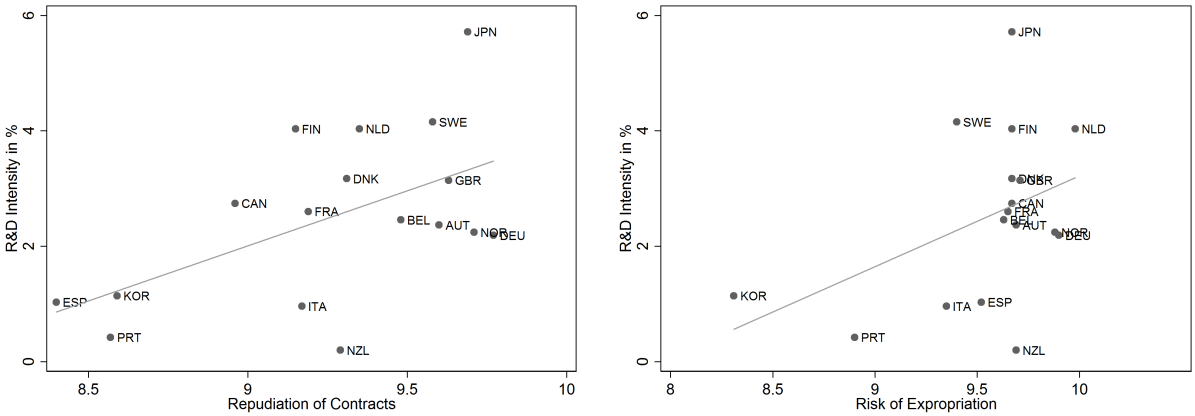
(a) Rule of Law Index

(b) Enforcement of Contracts



(c) Risk of Repudiation

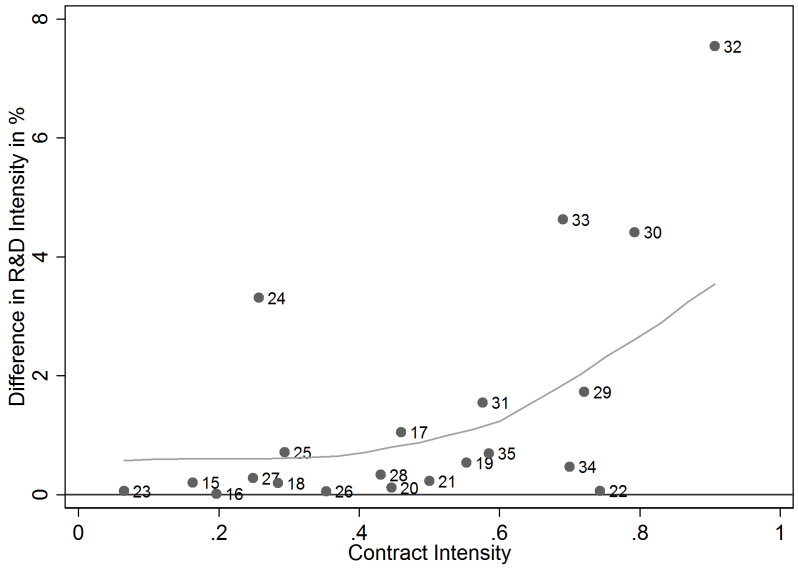
(d) Risk of Expropriation



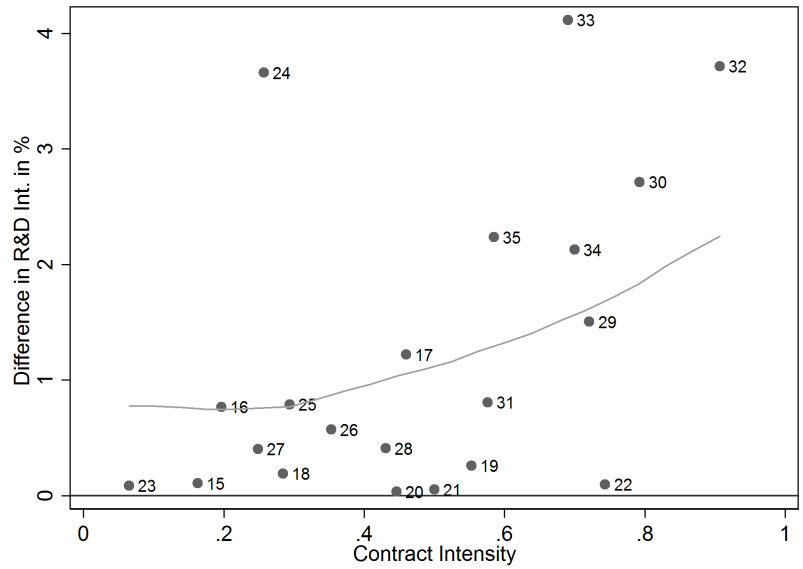
Note: This figure shows he relationship between R&D intensity in % and four different measure for the quality of the legal system across countries for the year 2005. The four different measures are (a) the Rule of Law Index of Kaufmann, Kraay, and Mastruzzi (2007), (b) Enforceability of Contracts from Djankov, Porta, Lopez-De-Silanes, and Shleifer (2003), (c) Risk of Expropriation and (d) Risk of Repudiation of Contracts from Porta, de Silanes, Shleifer, and Vishny (1998). For the description of the different measures please refer to Table 1. In all figures R&D intensity is on the vertical axis and the different measures for the legal system are on the horizontal axis.

Figure 2: Descriptive Evidence

(a) Contract Intensity and R&D: High vs. Low Rule of Law



(b) Contract Intensity and R&D: Germany vs. Italy



Note: In panel (a) we split the sample for the year 2005 at the median of the rule of law index of Kaufmann, Kraay, and Mastruzzi (2007) and plot the difference in R&D intensities for these two groups for different values of contract-intensities. Panel (b) shows the difference in R&D intensities of Germany and Italy depending on the contract-intensity of the industry. According to our data, Germany has a better rule of law than Italy. In all figures the difference in R&D intensities is on the vertical axis and the different measures and the measure for contract intensity of an industry is on the horizontal axis.

production is not available for all country-industry-year combinations to calculate the R&D intensities, the number of observations drops to 4,375.

In the first column our explanatory variables is the interaction term between the rule of law index and contract intensity. The control variables include country, industry and year fixed effects. In line with our theoretical predications a better contract environment has indeed an strong positive effect on R&D investments. The estimated coefficient for the interaction term between rule of law and contract intensity is significantly different from zero on 1% level. In the third and fourth column, we include factor endowment interactions for human and physical capital.[4] The estimated size of the coefficient is consistent with the estimate in the first column, but the statistical significance of the interaction term drops to the 5% level.

In column (3) and (4) we additionally control for other potential determinants of R&D investments unrelated to contract enforcement. For example high income countries potentially specialize in R&D intensive industries because they have a high value added, are more productive, produce complexer products or are particularly embedded in international trade and not because they have a good contracting environment. To capture this idea we control for (log) income per capita interacted with value added, TFP growth, input variety and intra-industry trade. We also add an interaction of the credit to GDP ratio with capital intensity to capture different financial development between rich and poor countries (Maskus, Neumann, and Seidel 2011). The estimated coefficients for TFP growth, intra industry trade and input variety are signficantly different from zero on conventional levels. The rule of law interaction term has again the expected sign and size and is still statistically different from zero on the 5% level.

Up to now we only considered the effect of the rule of law interaction term. However, our theory also predicts, that contract intensity has a negative impact on R&D investment (if we control for the interaction of rule of law and contract intensity). Yet, in our preferred specification (4) we are unable to identify the coefficient for contract intensity because it is perfectly collinear with the industry fixed effects. In the

[4]Since data on factor endowments is not available for all country-year combinations, the number of observations drops to 4,019.

specification reported in column (5) we leave out the industry fixed effects and find that — in line with our theory — the estimated coefficient is negative and statistically different from zero on the 10% level.

Table 5: The Determinants of R&D Investment

	(1) R&D Int.	(2) R&D Int.	(3) R&D Int.	(4) R&D Int.	(5) R&D Int.
Rule of Law x Contract Int. $\gamma \cdot \alpha$	1.14***	1.03**	1.29***	1.02**	0.98**
	(0.42)	(0.45)	(0.38)	(0.45)	(0.49)
Human Capital x Human Capital Intensity		0.18		0.21	0.53***
		(0.15)		(0.14)	(0.14)
Capital x Capital Intensity		0.05**		-0.01	0.05
		(0.02)		(0.02)	(0.09)
Log income x value added			-0.00	-0.01	0.05
			(0.05)	(0.05)	(0.07)
Log income x intra-industry trade			0.07**	0.09***	0.14**
			(0.03)	(0.03)	(0.06)
Log income x TFP growth			2.44**	2.52**	0.02
			(1.13)	(1.05)	(0.06)
Log credit/GDP capital x Capital Intensity			0.07	0.09	-0.09
			(0.20)	(0.21)	(0.07)
Log income x input variety			-0.03	-0.05*	-0.03
			(0.03)	(0.02)	(0.04)
Contract Intensity α					-3.38*
					(1.95)
Industry fixed effects	Yes	Yes	Yes	Yes	No
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.04	0.74	0.46	0.42	0.61
N	4375	4019	3615	3382	3382

Note: This table reports the results of OLS regressions of Equation **??**. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

In our preferred specification (4) with all controls, a one standard deviation increase in the judicial quality interaction term increases the dependent variable by 1.02 standard deviations while a similar increase in the human capital interaction term increases the dependent variable by 0.21 standard deviations.[5] If we take these estimates literally the effects of judicial quality on R&D investments is large not only in relative but also in absolute terms: For example, if Italy (rule of law: 7.26 in 2005) were to improve its judicial quality to the level of Germany (rule of law 8.23), then the R&D intensity of Italy's automobile industry (contract intensity: 70%) would increase from 2.21% to 2.85%.[6] As Germany's automobile industry has an R&D intensity of 4.34%, this estimate suggest that around 30% of the gap in R&D intensity between the automobile industry of Italy and Germany would be driven by the differences in the rule of law. Converting this number to Dollar terms, with the rule of law of Germany, the Italian Automobile Industry would increase their Research & Development Expenditure by $300 Million from $1.05 Billion to around $1.35 Billion.

Yet, the discussed theoretical framework does not relate to the rule of law index in particular nor does it necessarly feature R&D intensities as dependent variable. Therefore we test in the following if the described effect is also present over a range of plausible alternative dependent and independent variables. In particular, as the theoretical prediction stem from the impact of contractual institutions, the effect should be stronger if we use measures more directly related to the quality of contract enforcement while we would doubt our described causual mechansim if a measure more related to political stability would turn out to be a major determinant. The independent variable should be largely interchangeable as long as we measure some kind of irreversible investment which is related to production. Therefore it would be surprising if investment in physical capital for which active secondary markets might exist are more affected by the rule of law than investment in intangible assets.

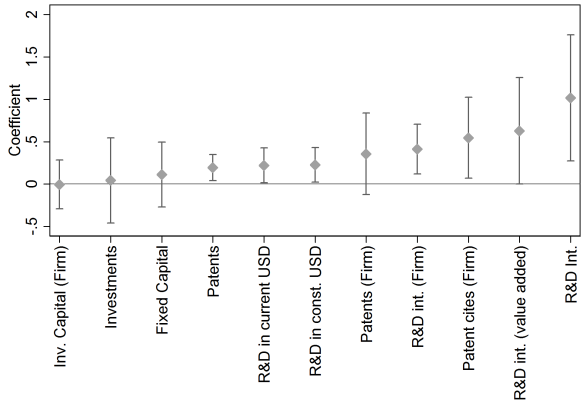
In line with our expectation, the results reported in panel (a) of Figure 3 indicate

[5]The estimates for the interactions for human capital may seem relatively low compared with the estimates for the interaction for judicial quality. However, they are of similar magnitude other studies have found (Nunn 2007, Levchenko 2008, Manova 2009).

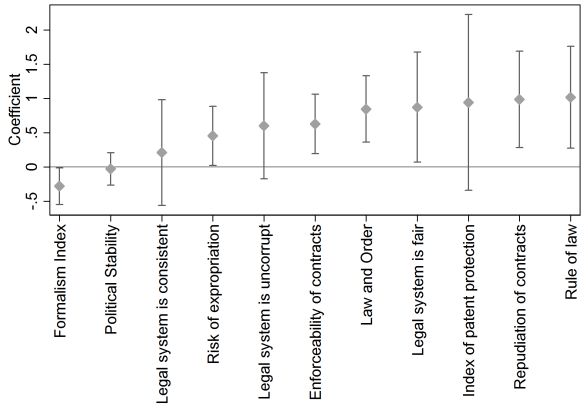
[6]This number is calculated by [Difference in Rule of Law / Std. Rule of Law * Contract Intensity * Coefficient * Std. of log(R&D investment)+1]*R&D Intensity=[(8.23-7.26)/1.78*0.7*1.02*0.74 +1]*2,21=2.85.

Figure 3: Different measures for the dependent and independent variable

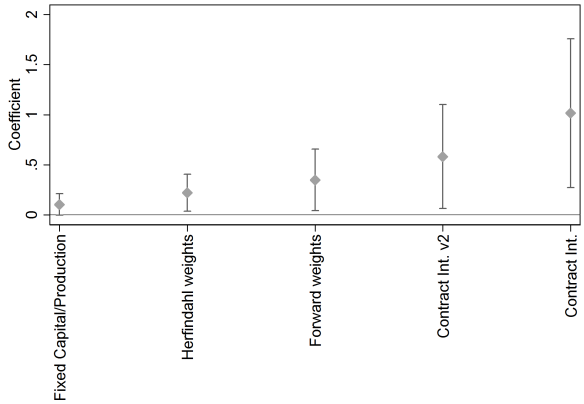
(a) Dependent Variable



(b) Independent Variable: Rule of Law



(c) Independent Variable: Contract Intensity



Notes: This figure shows the coefficients from our preferred specification for different dependent and independent variables. The range plots indicate the 90% confidence interval derived from two-way clustering on country and industry. All variable derived from the Compustat World Dataset are marked with "Firm".

that using independent variables related to fixed capital investment do not result in significant coefficients while almost all R&D measures, such as the absolute level of R&D investment or average patent counts and patent cites, work well. This is in line with our expectations as physical investment goods are more easily bought, sold and valued than immaterial goods. In panel (b) we use alternative measures for rule of law to construct the interaction term with contract intensity. As expected, measures which bear some relation with contract enforcement have more influence on R&D intensities than measures which are more related with the overall rule of law. For example polticial stability does not have any relation with R&D while the risk that a contract is repudiated has a strong influence on R&D investments. Interestingly, a formalism index has a significant negative impact, indicating that a more complex and less clear regulation might be negative for research. Lastly in panel (c) we use different measures for contract intensity, which all work reasonably well.

Additional Results

Vertical Integration

Given that rule of law is indeed important in vertical structures it is reasonable to assume that firms in badly governed countries try to overcome this obstacle by forward or backward integration. In general this should work against us finding any effect. Yet, this observation also delivers us another prediction: Rule of law should be relatively more important for R&D investments in industries in which it is harder to integrate. Unfortunately, unlike Acemoglu, Johnson, and Mitton (2009) we do not have a direct measure of integration for vertical integration and therefore have to use an imperfect measure: the number of inputs in an industry. The idea is, that if there are a lot of distinct inputs and each input has some fixed costs of production then the total costs of full integration is increasing in the number of inputs (Nunn 2007).

To test this idea we split the sample at the median number of inputs (100) and repeat our main regression and report the results in Table 6. According to our estimates, rule of law seems to be much more important in industries with a lot of inputs compared to industries with fewer inputs. The estimated coefficient for the

Table 6: Many Inputs

	(1) Few	(2) Many	(3) Few	(4) Many	(5) Few	(6) Many
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.17	2.07***	0.13	1.93***	-0.41	1.47***
	(0.48)	(0.38)	(0.49)	(0.46)	(0.38)	(0.51)
Human Capital x Human Capital Intensity			0.15	0.35*	0.14	0.30**
			(0.13)	(0.18)	(0.09)	(0.13)
Capital x Capital Intensity			0.06***	0.00	0.04	-0.07**
			(0.01)	(0.03)	(0.03)	(0.03)
Controls	No	No	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.76	0.68	0.77	0.69	0.80	0.72
N	2434	1941	2234	1785	1789	1593

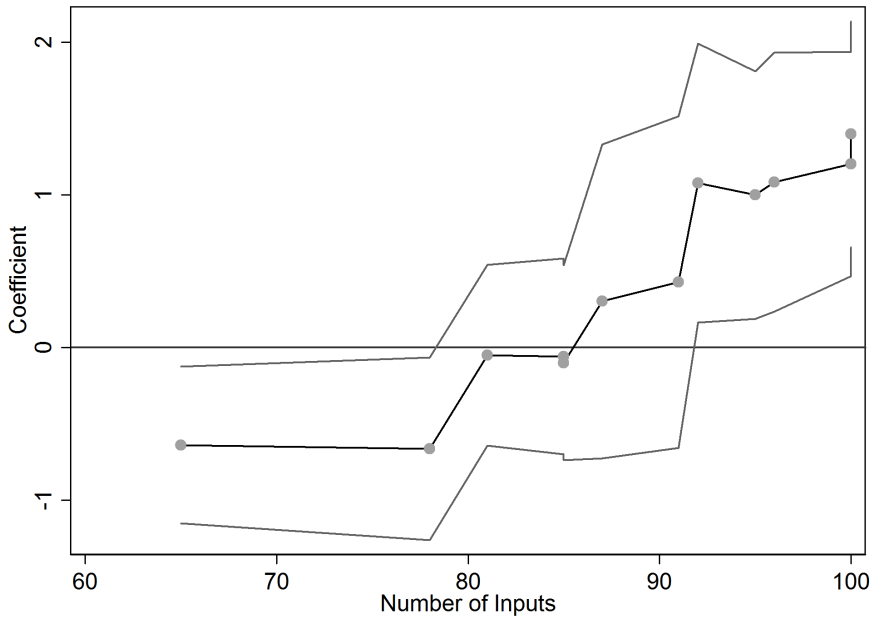
Note: This table reports the results of OLS regressions of Equation **??**. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. We split the sample at the median number of inputs, 100. The number of inputs is the minimum number of inputs used within an industry to produce a final good. We put all countries with inputs below 100 in the "Few" subsample while all countries with more inputs are in the "Many" subsample. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

industries with above median inputs, the "Many" sample, are larger than in our main specification. In industries with fewer than the median number of inputs, there is no discernible effect for rule of law interaction term. In order to show that this pattern is not a feature of the particular sample split, we sort all industries according to the number of inputs and redo the regression for different subsamples of ten industries in Figure 4. According to these estimates there is the exepected upward trend in the effect of rule of law with the number of inputs.

Robustness

If our results are robust they are not allowed to depend on the particular data sample. To show that this is the case, we selectively delete countries, industries and years from our sample and redo our analysis. In Figure 10 we plot the resulting coefficients. In terms of countries, leaving out Hungary and Poland seem to have the strongest impact and the estimated coefficient becomes even insignificant. This is not surprising given that our effect is most pronounced in countries with a weak rule of law. In Table 12 we repeat our main regression first without Poland and Hungary and get the expected

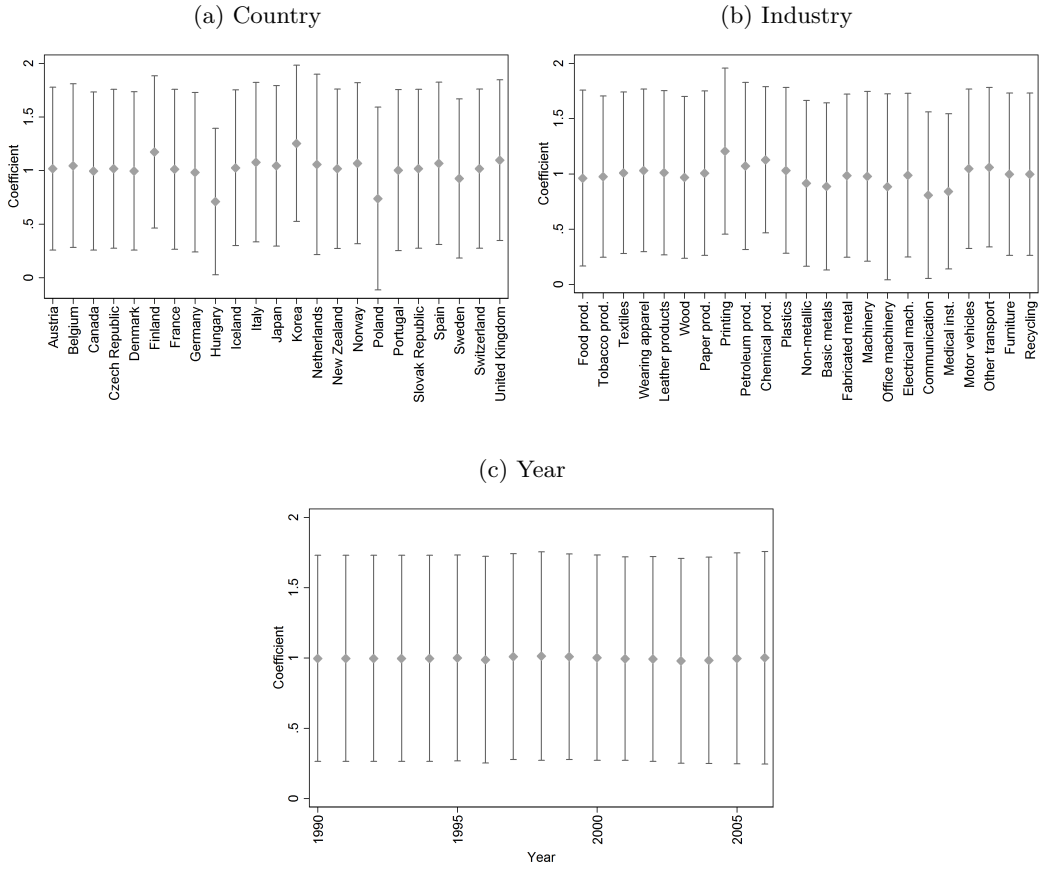
Figure 4: Impact of Rule of Law depending on the number of inputs



Notes: This figure displays the regression coefficients of the rule of law interaction term on R&D intensity. To arrive at our estimation sample, we sort the industries according to the minimum number of inputs used in the industry. Then we select for the first data point the ten industries with the least number of inputs as estimation sample. For each following data point we add one industry with the next highest number of inputs and drop the industry with the lowest number of inputs in our sample. The horizontal axis displays the minimum number of inputs within the estimation sample.

insignificant coefficient estimate. If we additionally leave out two countries with a particular good rule of law, Finland and Iceland, the effect is again significant on conventional levels. In terms of industries, our results are most sensitive to leaving out industries with a lot of inputs such as "Office machinery" and "Communication equipment" (Figure 10). If we again balance the sample by also excluding industries with particular few inputs such as "Printing" and "Chemicals" the effect returns (Table 12). Deleting any particular year does not seem to have any measurable impact.

Figure 5: Robustness Check: Leave-one-out estimation



Notes: This figure shows the relationship between R&D intensity and rule of law interaction term if we delete a particular country, industry or year from our sample. On the horizontal axis the country, industry or year which is left out is described. On the vertical axis, the size of the coefficient is depicted.

As a further robustness check we re-estimate our main specification on another

Table 7: Robustness: Countries and Industries

	(1) R&D Int.	(2) R&D Int.	(3) R&D Int.	(4) R&D Int.
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.15	0.28***	0.32	0.83**
	(0.16)	(0.06)	(0.43)	(0.36)
Human Capital x Human Capital Intensity	0.40***	0.42***	0.18	0.26
	(0.16)	(0.16)	(0.11)	(0.16)
Capital x Capital Intensity	0.00	0.00	-0.01	-0.01
	(0.02)	(0.02)	(0.03)	(0.03)
excluding	Poland	Poland	Office Mach.	Office Mach.
excluding	Hungary	Hungary	Comm.	Comm.
excluding		Finland		Printing
excluding		Iceland		Chemicals
N	2985	2677	2992	2705

Note: This table reports the results of OLS regressions of Equation 4. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. To arrive at our estimation sample we exclude the countries and industries indicated in the last four rows. In all regressions we control for all control variables and fixed effects of our preferred specification. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

data sample derived from the Compustat Global Database and report the results in Table 13. In the first five columns we report the results from regressions on the country-year-industry level. In the last column we use the disaggregated firm level dataset. All standard errors are clustered on the country and industry level. In this dataset we can additionally use the number of patents and the number of cites as an outcome measure. In the specification with all control variables, column (3), the mean estimate of the coefficient of the rule of law interaction term is approximately half the size of the effect in the main regression results. Furthermore, there appears to be a positive impact of rule of law on cites, yet the effect on the number of patents is not significantly different from zero on conventional levels. In line with our expectations, the results are the same on the aggregated and on the firm level data.

Table 8: Compustat Dataset

	(1) R&D Int.	(2) R&D Int.	(3) R&D Int.	(4) # Patents	(5) # Cites	(6) R&D Int.
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.41**	0.47**	0.41**	0.36	0.55*	0.41**
	(0.18)	(0.18)	(0.18)	(0.29)	(0.29)	(0.16)
Employment/Output		-0.08	-0.07	0.03	0.01	0.00
		(0.05)	(0.06)	(0.04)	(0.05)	(0.05)
Capital/Output		0.39***	0.40***	0.06	0.02	0.28***
		(0.06)	(0.06)	(0.05)	(0.05)	(0.06)
Controls	No	No	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.69	0.76	0.77	0.55	0.56	0.53
N	5606	4538	4227	4227	4227	17542

Note: This table reports the results of OLS regressions of Equation 4. The estimation sample is derived from the CompuStat Global Database and the NBER Patent Citation File. In the first five specification the data is aggregated on the country-industry-year level. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Endogeneity

As mentioned above, our estimation strategy might suffer from reverse causality: Countries with contract intensive industries could be more keen to improve their contracting environment. If this is the case, rule of law would be positively correlated with the error term and we would overestimate the effect of rule of law on investment in R&D. To get an sense how severe this problem might be we first pursue two OLS-based strategies to bound the effect before turning to instrumental variable results. First we assume a particular correlation between the error term and our rule of law-interaction term and plot the resulting coefficient in panel (a) of Figure 6 (Kiviet 2012). According to these estimates, the effect of the rule of law interaction term is significantly different from zero as long as the correlation is lower than 0.4. This implies that changes in R&D intensity must explain around 16% of the variance in the interaction coefficient of rule of law and contract intensity. To eradicate the complete effect in the mean estimate the reverse causality must explain at least 81% of the variance in the interaction term (0.9 correlation coefficient).

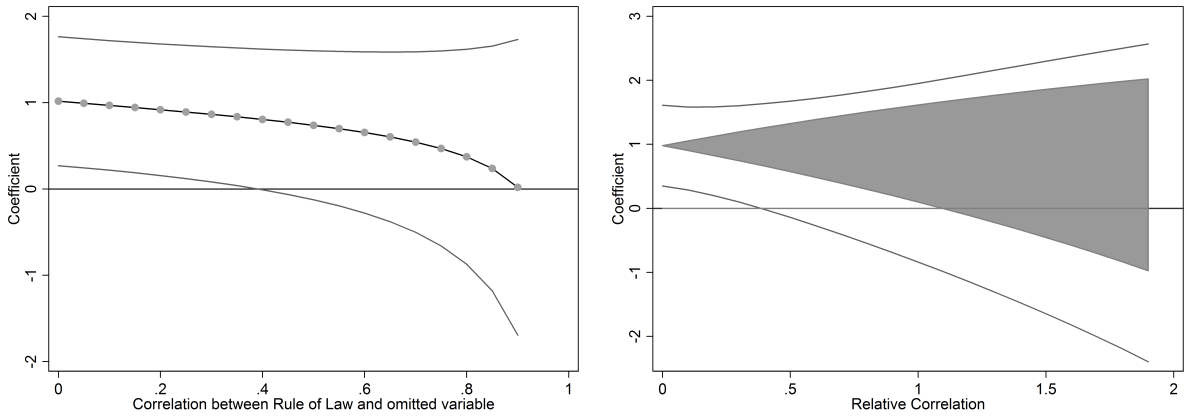
These number appear quite high, yet it is easier to gauge their significance compared to the effect of the other control variables. Therefore — as a second alternative — we place restrictions on the correlation between the rule of law-interaction term and the error term relative to the correlation between the interaction term and observed control variables. We adopt this method from Krauth (2011).[7] The reason to use a relative correlation is, that correlation of the interaction term with observed variables might give an idea how high the correlation is with the unobserved variables. In our case of reverse causality, the influence of our control variables on the rule of law interaction term should be similar in magnitude to the effect of R&D on the interaction term. According to the estimated set of coefficients reported in panel (b) of Figure 6, the left out variable must have at least 50% of the correlation of the seven other control variables to render our estimates insignificant. In addition, the effect is driven to zero only if the reverse causality can explain at least the same amount of variation in the rule of law-interaction term than all other control variables

[7] We thank Brian Krauth for his help in adapting the estimation program.

Figure 6: Sensitivity

(a) Bias Corrected OLS

(b) Relative Correlation Restriction



Notes: This figure displays the OLS regression coefficients of Rule of Law on R&D intensity. The coefficient is calculated under the assumption of a positive correlation between the rule of law interaction term and the error term. In panel (a) the assumed correlation is given on the horizontal axis in absolute values, while in panel (b) the coefficient is calculated relative to the correlation of the explanatory variables and the remaining non-constant control variables.

combined.

A strategy to deal directly with reverse causality is to use instrumental variable regression. In the following we use legal origin as instruments to isolate variation in rule of law across countries which might be unaffected by the variation of R&D investment from 1995 to 2005. The results of this exercise are presented in 9. In contrast to our expectations the size of the IV estimates exceeds in all specification the OLS estimates. There are potentially two reasons for this: First, if the correlation of rule of law and the error term is negative instead of positive, we are reporting with the OLS estimate already a lower bound (Nevo and Rosen 2012). Second, legal origin might by itself has an influence on R&D investments violating the exclusion restriction necessary for a proper intstrument. To explore this possibility we use the recent method of Conley, Hansen, and Rossi (2012) and report the resulting set estimates and confidence bands in Figure 7.

We use two different methods: The first set of confidence intervals is constructed as a union of all confidence bands for all possible values of the influence of legal origin between zero and the value indicated on the horizontal axis. These bands

Table 9: Instrumental Variable Results

	(1) OLS	(2) IV	(3) OLS	(4) IV
Rule of Law x Contract Int. $\gamma \cdot \alpha$	1.02**	1.51**	0.96***	0.54***
	(0.45)	(0.70)	(0.28)	(0.16)
F-test		44.70		
F-test (p-value)		0.00		
Sargan-test (p-value)		0.16		
Controls	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	No	No
Year fixed effects	Yes	Yes	Yes	Yes
N	3382	3382	3382	3382

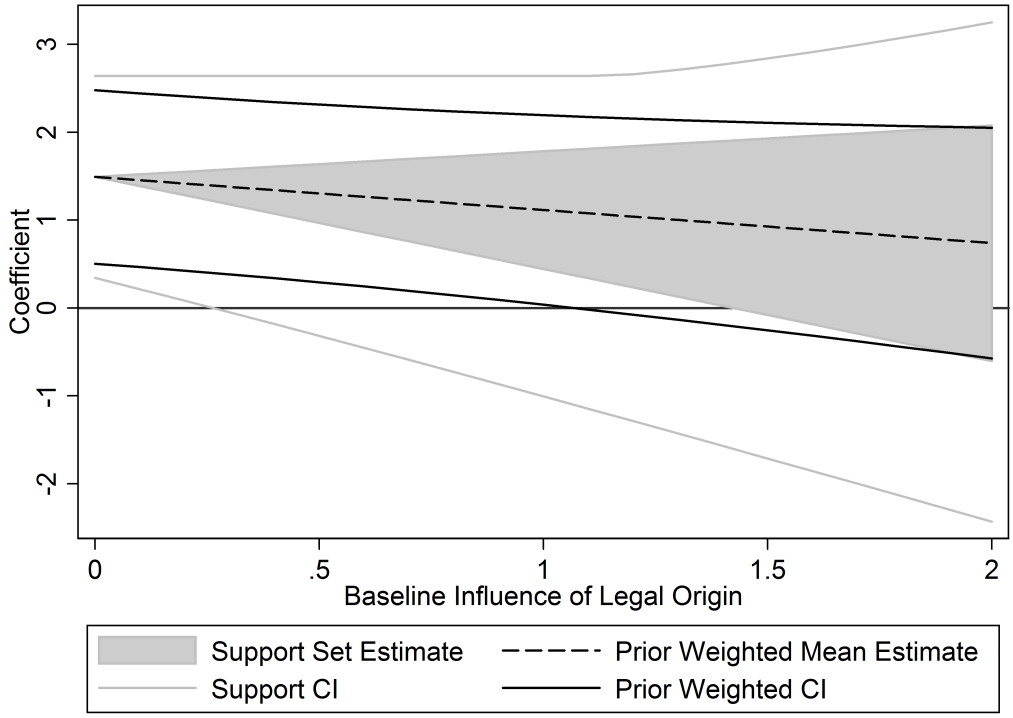
Note: This table reports the results of OLS and Instrumental Variables (IV) regressions of Equation 4. We use the legal origin of a country as instrument. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

are the most conservative in this picture. The second set of confidence bands are calculated under the assumption that the baseline influence is drawn from a uniform distribution with a support from zero to the value of horizontal axis. Assuming that the first method is correct, the effect of rule of law is still significantly different from zero on the 5% level if a particular legal origin can increase R&D intensity by more 0.4 standard deviations (i.e an increase of 29 %) - after accounting for the direct effect of legal origin on rule of law. Following the result from the second method, the effect of the interaction term is only zero if the the influence of legal origin is as large as a one standard deviation increase in rule of law (i.e. 74%).

5 Conclusion

In this article we study the effect of rule of law on R&D investments for 23 OECD countries in 22 manufacturing industries for the period 1996 to 2006. We find that companies in countries with good contracting institutions have higher R&D investments, especially in industries that are contract intensive. According to our estimates,

Figure 7: Confidence Intervals for Instrumental Variables



Notes: This figure presents 95% confidence intervals for two methods under the assumption that the instrumental variable also has an baseline influence on research & development. On the horizontal axis we vary the baseline influence of legal origin in terms of standard deviations of R&D intensity. In the first method ("Set") the baseline influence is the maximum indicated on the horizontal axis. In the second method ("Prior Weighted"), the baseline influence is drawn from a uniform distribution between zero and the value indicated on the horizontal axis.

improving the contracting environment in a country has sizable economic effects on the levels of R&D investment. The results are robust over a wide range of plausible dependent and independent variables. The effects are stronger for countries which have a bad rule of law to start with and for industries in which it is harder to vertically integrate. To correct for potential reverse causality we bound the OLS estimates and use instrumental variable techniques. The results of these methods show that our findings are only overturned if the reverse causality is of an large magnitude.

Given the prominent role of R&D investments as a key driver of economic growth, policymakers around the world have strongly promoted R&D investments, by providing tax incentives, direct and indirect subsidies and infrastructural support. Our results show that improving the contracting environment is also important for R&D spending, especially in sectors that produce more complex goods. This study underscores the importance of a good judicial system if R&D investments are a major policy concern. Policymakers may wish to remove impediments resulting from an inefficient legal and judicial system to attract and promote higher R&D investments in order to improve the innovative capacity of their economy.

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Appendices

A Nonlinear Effects

Up to now we were only concerned with estimating the effect of rule of law on the mean of R&D intensity. But, in this particular application there might be important nonlinear effects: For example, there might be threshold level above which a better rule of law has no effect. Or rule of law might only be important if an industry has a low level of R&D to begin with, while it might have no effect for research intensive countries or industries. In this section we therfore drill a bit deeper and estimate the effect over the whole distribution of the dependent and independent variable.

First, we estimate quantile regressions and report the results for selected quantiles in Table 10 and for all quantiles in Figure 8a. The coefficients follow an inverse U-shape implying that rule of law might be more important for industries with a low R&D intensity to begin with. To come back to our example from above, the Italian automobile industry is almost at the 75 % quantile implying that the appropriate coefficient is 0.47. Then if we again calculate the counterfactual research intensity for an increase of the rule of law to the level of Germany, the counterfactual research intensity is 2.50 instead of 2.85. Therefore we expect that around 13% of the difference in research intensity between the German and the Italian automobile industry is accounted for by rule of law. If we convert this figure into Dollar terms, then the Italian automobile industry would increase their annual research and development by around $139 Million to $1.19 Billion.

In the second panel of Figure 8 we estimate a local polynomial regression of R&D intensity on the rule of law interaction term. For both variables we partial out all controls and fixed effects of our preferred specification. According to this graph the effect of the rule of law interaction term is stronger for lower values of rule of law and becomes weaker when rule of law increases. However, this graph is difficult to interpret quantitatively, because the explanatory variable is a composite of contract intensity and rule of law. As we consider contract intensity as a fixed and industry specific feature we are most interested in the effect of rule of law, i.e. to compare the

Table 10: Quantile Regression

	(1) 5%	(2) 25%	(3) 50%	(4) 75%	(5) 95%
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.51***	1.21***	0.93***	0.47***	0.30
	(0.08)	(0.11)	(0.11)	(0.11)	(0.19)
Human Capital x Human Capital Intensity	0.06*	0.20***	0.29***	0.27***	0.30***
	(0.04)	(0.05)	(0.05)	(0.05)	(0.08)
Capital x Capital Intensity	-0.03	-0.02	0.03	0.04	-0.00
	(0.02)	(0.03)	(0.03)	(0.03)	(0.05)
R&D Int.	0%	0.15%	0.55%	2.1%	8.77%
Controls	Yes	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes
N	3382	3382	3382	3382	3382

Note: This table reports the results of an Quantile regression of Equation **??**. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. Standardized beta coefficients are reported, with standard errors in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

size of the effect countries with a good rule of law compared to countries with a bad rule of law.

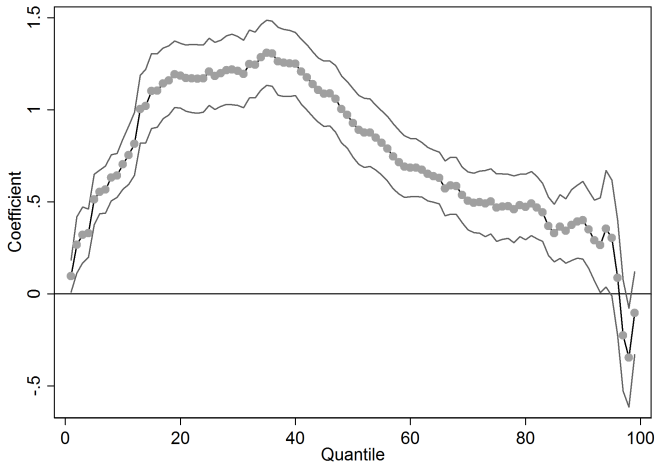
To do this we order the different countries according to their rule of law and split the sample at the median. The result are reported in Table 11 and indicate that the effect of the rule of law interaction term is higher in countries with a worse rule of law. To get a more complete picture, we repeat our analysis on groups of countries and plot the resulting coefficients in Figure 9. To arrive at the first data point we use the subsample of the ten countries with the worst rule of law, redo our regression and plot the resulting coefficient. For the next regression we add the country with the next highest rule of law and drop the country with the lowest value from the group. The resulting estimates indicate, that the effect of the interaction term is not significantly different from zero if the rule of law is higher than 7.3. Thus it might not have an large impact on R&D to increase the rule of law of Germany from 8.23 to the level of Finland (8.78).

B Robustness

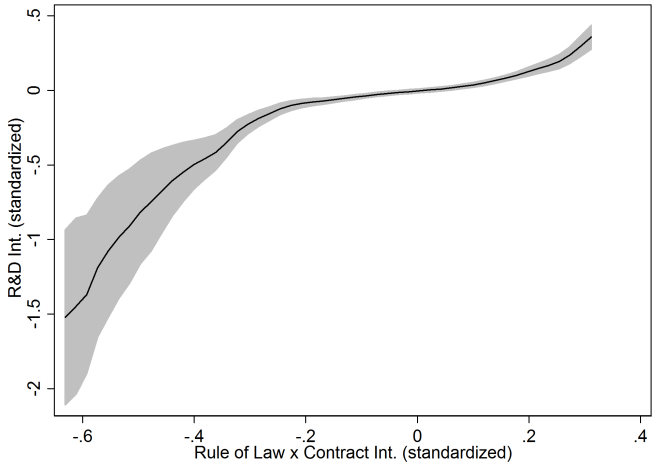
If our results are robust they are not allowed to depend on the particular data sample. To show that this is the case, we selectively delete countries, industries and years from

Figure 8: Nonlinear Effects

(a) Quantile Regression



(b) Local Polynomial Regression



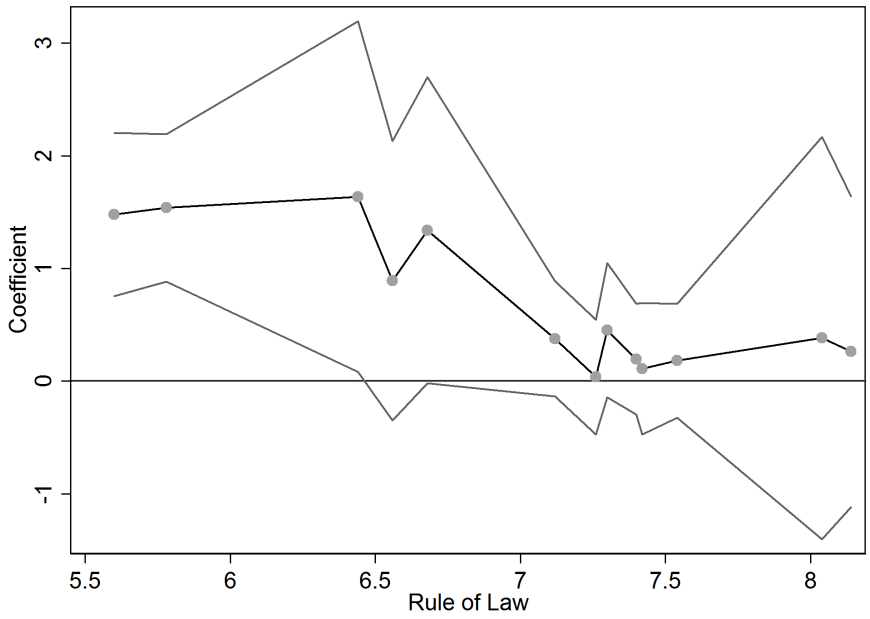
Notes: Both figures show the relationship between R&D intensity and the interaction of Rule of Law and Contract Intensity. In the upper figure we report the resulting coefficients for a quantile regression for all quantiles between 1 and 99. In the lower figure we plot the result of a local polynomial regression. The bounds indicate in both cases the 90% confidence interval.

Table 11: Rule of Law Subsample

	(1) Low	(2) High	(3) Low	(4) High	(5) Low	(6) High
Rule of Law x Contract Int. $\gamma \cdot \alpha$	1.39***	0.37	1.54***	0.34	1.46***	-0.16
	(0.45)	(0.60)	(0.58)	(0.61)	(0.53)	(0.42)
Human Capital x Human Capital Intensity			0.12	0.08	0.14	0.13
			(0.22)	(0.07)	(0.19)	(0.10)
Capital x Capital Intensity			0.02	0.08***	-0.06***	0.03
			(0.03)	(0.02)	(0.02)	(.)
Controls	No	No	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.75	0.72	0.78	0.72	0.80	0.74
N	2295	2080	1939	2080	1734	1648

Note: This table reports the results of OLS regressions of Equation **??**. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. We split the sample at the median of rule of law. We put all countries with a rule of law index below 7.81 in the "Low" subsample while all countries with a higher rule of law are in the "High" subsample. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

Figure 9: Impact of Rule of Law Interaction depending on Rule of Law



Notes: This figure displays the regression coefficients of the rule of law interaction on R&D intensity. To arrive at our estimation sample, we sort the countries according to rule of law. Then we select for the first data point the ten countries with the lowest rule of law as estimation sample. For each following data point we add one country with the next highest rule of law and drop the country with the lowest rule of law in our sample. The horizontal axis displays the minimum rule of law within the estimation sample.

Table 12: Robustness: Countries and Industries

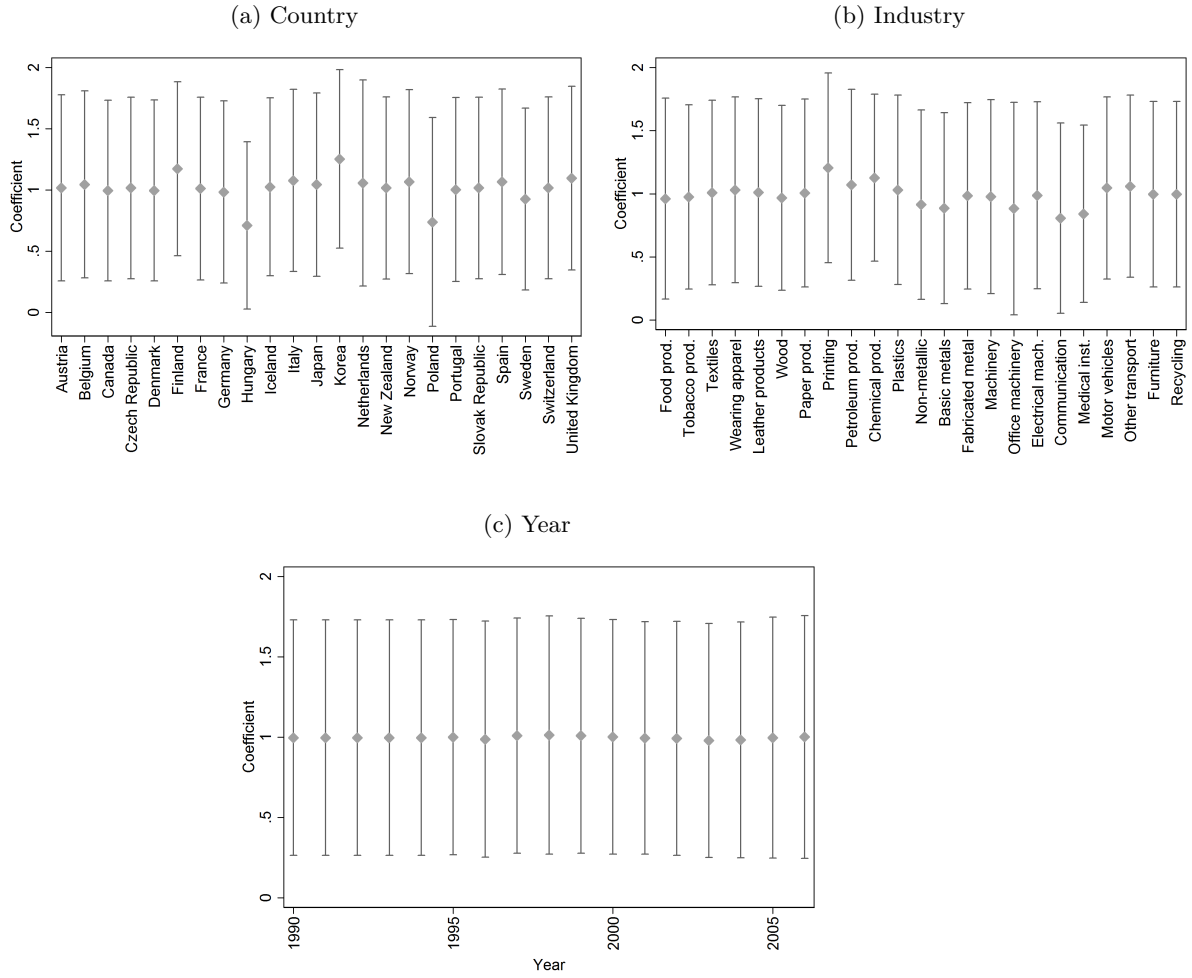
	(1) R&D Int.	(2) R&D Int.	(3) R&D Int.	(4) R&D Int.
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.15	0.28***	0.32	0.83**
	(0.16)	(0.06)	(0.43)	(0.36)
Human Capital x Human Capital Intensity	0.40***	0.42***	0.18	0.26
	(0.16)	(0.16)	(0.11)	(0.16)
Capital x Capital Intensity	0.00	0.00	-0.01	-0.01
	(0.02)	(0.02)	(0.03)	(0.03)
excluding	Poland	Poland	Office Mach.	Office Mach.
excluding	Hungary	Hungary	Comm.	Comm.
excluding		Finland		Printing
excluding		Iceland		Chemicals
N	2985	2677	2992	2705

Note: This table reports the results of OLS regressions of Equation **??**. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. To arrive at our estimation sample we exclude the countries and industries indicated in the last four rows. In all regressions we control for all control variables and fixed effects of our preferred specification. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

our sample and redo our analysis. In Figure 10 we plot the resulting coefficients. In terms of countries, leaving out Hungary and Poland seem to have the strongest impact and the estimated coefficient becomes even insignificant. This is not surprising given that our effect is most pronounced in countries with a weak rule of law. In Table 12 we repeat our main regression first without Poland and Hungary and get the expected insignificant coefficient estimate. If we additionally leave out two countries with a particular good rule of law, Finland and Iceland, the effect is again significant on conventional levels. In terms of industries, our results are most sensitive to leaving out industries with a lot of inputs such as "Office machinery" and "Communication equipment" (Figure 10). If we again balance the sample by also excluding industries with particular few inputs such as "Printing" and "Chemicals" the effect returns (Table 12). Deleting any particular year does not seem to have any measurable impact.

As a further robustness check we re-estimate our main specification on another data sample derived from the Compustat Global Database and report the results in Table 13. In the first five columns we report the results from regressions on the country-year-industry level. In the last column we use the disaggregated firm level

Figure 10: Robustness Check: Leave-one-out estimation



Notes: This figure shows the relationship between R&D intensity and rule of law interaction term if we delete a particular country, industry or year from our sample. On the horizontal axis the country, industry or year which is left out is described. On the vertical axis, the size of the coefficient is depicted.

dataset. All standard errors are clustered on the country and industry level. In this dataset we can additionally use the number of patents and the number of cites as an outcome measure. In the specification with all control variables, column (3), the mean estimate of the coefficient of the rule of law interaction term is approximately half the size of the effect in the main regression results. Furthermore, there appears to be a positive impact of rule of law on cites, yet the effect on the number of patents is not significantly different from zero on conventional levels. In line with our expectations,

Table 13: Compustat Dataset

	(1) R&D Int.	(2) R&D Int.	(3) R&D Int.	(4) # Patents	(5) # Cites	(6) R&D Int.
Rule of Law x Contract Int. $\gamma \cdot \alpha$	0.41**	0.47**	0.41**	0.36	0.55*	0.41**
	(0.18)	(0.18)	(0.18)	(0.29)	(0.29)	(0.16)
Employment/Output		-0.08	-0.07	0.03	0.01	0.00
		(0.05)	(0.06)	(0.04)	(0.05)	(0.05)
Capital/Output		0.39***	0.40***	0.06	0.02	0.28***
		(0.06)	(0.06)	(0.05)	(0.05)	(0.06)
Controls	No	No	Yes	Yes	Yes	Yes
Industry fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Country fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes
Adj. R2	0.69	0.76	0.77	0.55	0.56	0.53
N	5606	4538	4227	4227	4227	17542

Note: This table reports the results of OLS regressions of Equation **??**. The estimation sample is derived from the CompuStat Global Database and the NBER Patent Citation File. In the first five specification the data is aggregated on the country-industry-year level. The dependent variable is the natural logarithm of R&D intensity in a particular country and industry. Standardized beta coefficients are reported, with standard errors clustered on country and industry in brackets. *, ** and *** indicate significance at the 10, 5 and 1 percent levels, respectively.

the results are the same on the aggregated and on the firm level data.