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# DETERMINANTS OF INTERNATIONAL ACTIVITY: EVIDENCE FROM THE CHEMICAL INDUSTRY

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# ABSTRACT

## Determinants of International Activity: Evidence from the Chemical Industry*

This Paper empirically investigates two important determinants of international activity through wholly owned operations, joint-ventures and licensing, namely country risk and IPRs protection. Using a comprehensive database on investments in chemical plants during the period 1981-96, we show that higher levels of country risk are associated with less activity into recipient economies. The analysis also suggests that international activity with smaller resource commitment tends to be preferred in countries with higher levels of risk, and that multinational investment is more responsive to changes in risk conditions than indigenous investment. After controlling for several country characteristics, we do not find IPRs protection playing a significant role in fostering international activity or conditioning its mode.

JEL Classification: F21, F23, O32 and O34
Keywords: chemical industry, country risk, foreign direct investment, IPRs protection and technology licensing

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## 1. Introduction

The past decade has been marked by the upsurge of firms' involvement outside national borders. The 2002 World Investment Report shows that the worldwide flow of foreign direct investment has passed from slightly more than $200 billion in 1992 to about $700 billion in 2001. Arora et al. (2001) have stressed the increased importance of market-based transactions for technology in the last two decades of the XX century. Their estimates indicate a worldwide market for technologies in the range of $35-50 billion, of which a large chunk is due to cross-border deals. International alliances and joint ventures have also become widespread in the last few years. From a strategic point of view, since the need to exploit technological assets outside national borders has become more and more imperative, companies must have a good understanding of trends in international expansion. From a policy point of view, governments seeking to attract international technology must be concerned about the factors that enhance or hinder foreign direct investment and licensing, which are leading channels through which technology moves across borders. This papers focuses on two important determinants of international activity through wholly owned operations, joint-ventures and licensing, namely country risk and IPRs protection.

Although all business transactions involve some degree of risk, when they occur across international borders they carry additional risks not present in domestic transactions. Country risk analysis rests on the fundamental premise that growing imbalances in economic, social, or political factors increase the risk of shortfall in the expected return of an investment. The available evidence shows that many countries have experienced important changes in their idiosyncratic risk during the 90s. Indeed, countries like Yugoslavia and Iraq have more than doubled their level of risk. Similarly, countries like Indonesia, Cameroon, Pakistan and Algeria have experimented very significant increases. On the other side, Poland, El Salvador, Peru, Costa Rica and Panama have more than halved their level of country risk.[1]

Firms, and managers in particular, seem to place a lot of attention on the changes of investment conditions in different countries. Anecdotal facts suggest that rises in country-specific risk have an immediate effect on international investment that is often considered footloose and ready to move to safer places. The proliferation of country ratings, which should serve as an aid to decision-making in the assessment of country risks, and the rise of specialized consultancy companies, like Control Risks Group, provide further evidence of the close relationship between international investment and country-specific risk.

The main objective of this paper is to offer a closer look at the impact of country risk on the international activity of multinational firms. By exploiting a comprehensive data set on plant-level investments in the worldwide chemical industry during the period 1981-1996 we are able to distinguish between three modes of international expansion: wholly owned operations, joint-ventures and technology licensing.[2] We account for the simultaneity of the mode choice. In addition, we estimate the relative effect of country risk on wholly owned operations, joint-ventures and technology licensing, and disentangle the impact of country risk on investments by local and multinational firms.

The second objective of this research is to address the ongoing debate on the importance of policies aimed at stricter enforcement of intellectual property rights (IPRs). Advocates of these policies argue that stronger IPRs protection would enhance technology flows and foreign downstream investment in the recipient countries. This view has been echoed in the introduction of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPs). Opponents suggest that stricter enforcement of IPRs would reinforce the monopoly power of large multinational corporations. Indeed, many developing economies are not eager to strengthen their IPR legislation and its enforcement fearing that the losses resulting from this action would outweigh the benefits. After controlling for other country characteristics, our results show that, at least for the chemical industry, international activity through wholly owned operations, joint-ventures and licensing does not seem to be sensitive to the degree of protection of IPRs. At the

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[1] These figures are obtained by comparing the Institutional Investor Credit Ratings (IICR) of the different countries at the beginning of the year 1990 and at the end of 1999. See later for details on the IICR.

[2] The chemical industry constitutes an ideal test-bed for addressing our research questions since it is a global technology-based industry. Moreover, the amount of investment to start up a chemical plant is substantial, which makes country risk analysis more important. In addition, the industry has developed a long tradition of technology licensing.

very least, this suggests that further research is needed to support either of the two sides of the debate.

## 2. Related Literature and Contribution

The main contribution of this paper is to provide a systematic and econometrically sound investigation of two important determinants of international activity: country risk and IPRs protection.

There is an empirical literature focused on country risk as an explanatory factor for the amount of foreign direct investment in a given country. However, little is known about other channels of international expansion, most notably technology licensing. We also distinguish between wholly owned operations and joint-ventures. One of the first studies that analyzed the relationship between risk and foreign direct investment is Flamm (1984). He estimates an equation relating multinational electronics investments to relative wages, using country-specific dummy variables as proxies for differential risk. His results seem to suggest that firms are very much concerned with having a balanced risky portfolio so they respond quickly to changes in country risk. Wheeler and Mody (1991) also investigate the impact of country-specific risk on foreign direct investment. They measure risk as a first principal component extracted from a set of indices which measure political stability, inequality, corruption, red tape, quality of the legal system, cultural compatibility, attitude toward foreign capital and general expatriate comfort. They find that firms seem to assign little importance to perceived risk, except for some modest weight attached to geopolitical considerations. Bevan and Estrin (2000), using a panel data set containing information on foreign direct investment flows from 18 market economies to 11 transition economies over the period 1994-1998, find that foreign direct investment inflows are strongly influenced by country risk, among other factors. More recently, Albuquerque (2003), using aggregate data on investment in a large set of countries, shows that the share of foreign direct investment inflows to gross flows is negatively correlated to several creditworthiness and country risk ratings. He argues that foreign direct investment is harder to expropriate than other financial flows. However, he does not provide estimates of the impact of country risk on the absolute volume of foreign direct investment.

Our paper shows that the whole flow of international activity into a recipient economy is negatively related to the level of country risk. Moreover, this effect holds for all three modes considered in our analysis, namely wholly owned operations, joint-ventures and technology licensing. In addition, we are also able to show that the relative effect is stronger for modes that involve greater commitment with the recipient country, such as wholly owned operations. In sum, higher levels of country risk mean less international activity, which tends to be more market-based. Finally, we disentangle the impact of country risk on investments by local and multinational firms, and show that international investment tends to be more footloose and ready to move to safer places.

This paper also contributes to the growing literature on international technology transfers and IPRs protection. The findings of this literature have been mixed so far (Maskus, 1998). For instance, Lee and Mansfield (1996) report a positive and significant impact of IPRs on foreign direct investment flows. However, Fink (1997) shows that, if it exists at all, the relationship between IPRs and multinational activity is negative. Few studies have addressed the link between other means of international technology transfers and IPRs. Smith (2001) shows that IPRs have a positive and significant effect both on foreign direct investment and licensing. The effect is more pronounced for licensing and tends to be stronger in countries with strong imitative abilities. However, Branstetter et al. (2002) find no evidence of an increase in technology licensing to unaffiliated parties due to stricter enforcement of IPRs, and Maskus et al. (2003) report that in lower-technology industries it is more likely that stronger IPRs would induce firms to shift toward lesser use of licensing. In our paper we cannot find any significant relationship between the strength of IPRs protection and the flows of international activity, irregardless of the mode chosen by the investor.

Two important limitations should be noted. First, we do not have exports figures, so our analysis is limited to international expansion modes that imply the transfer of production to the recipient country. A firm could exploit its technological advantage abroad simply by producing at home and serving the foreign market through exports. Second, we have data from only one industry, so that the extent to which our results can be exported to other industries remains unclear.[3]

## 3. Theoretical Background and Hypotheses

Most theoretical research on firms' internationalization builds on the premise that firms have assets that confer them an advantage in servicing a foreign market (Hymer, 1976). Such assets include intangibles such as knowledge and technology. Firms first decide whether to serve the foreign market through exports or by locating the production abroad. Once the decision to locate the production abroad is taken, firms have several modes available to organize their international activity, among them, wholly owned operations, joint-ventures and technology licensing (Dunning, 1981; Markusen, 1995). In this paper we will focus only on international activity that implies the transfer of production in the foreign country.

The relationship between risk and the level of international activity in a country is straightforward. Other things being equal, higher country risk reduces the expected profits from international investment and hence the propensity to invest (Wheeler and Mody, 1991). So, one should expect a reduction in the expected profits of any of the three forms of international expansion analyzed here.[4] This is straightforward in the case of wholly owned operations, where the investor is the residual claimant of all possible profits, and in the case of joint-ventures, where the investor typically receives a share of the whole profits, but it is also true for technology licensing, where royalties and other types of payments tend to be, although spuriously, related to the expected profits obtainable through the exploitation of the technology.

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[3] The lack of exports figures might not be a serious problem in the chemical industry where the key upstream input – technology – is easier to move across locations, while the final products (chemicals such as ammonia and ethylene) are costly to transport. Concerning the applicability of our results to other industries, we believe that they should be extendable to other global high-tech industries (for instance, electronics). The test of this conjecture is left to future research.

[4] Albuquerque (2003) shows that foreign direct investment has a sharing risk advantage over other capital flows because an important component of foreign direct investment is due to intangible assets that are inalienable to a large extent. This makes foreign direct investment less sensitive to country risk vis-à-vis other financial flows.

Let the outside best option for the investor (it could be not serving at all a given foreign market or exporting) be independent of (or less respondent to) changes in country risk, then the following proposition follows immediately:

**Proposition 1**: *The flow of international activity into a given country is negatively related to the level of country risk.*

Notice that this does not imply that the flow of each of the three forms of international activity considered here increases when the level of country risk decreases. In fact, the relative effect of changes in the level of country risk is more subtle. The three modes involve a very different level of resource commitment (Dunning, 1981; Hill, Hwang and Kim, 1990). By resource commitment we mean dedicated assets that cannot be redeployed to alternative uses without cost (loss of value). These assets may be tangible (e.g. physical plant) or intangible (e.g. management know-how). In the case of technology licensing, the licensee bears most of the costs of opening up and serving the foreign market. In the case of a wholly owned operation, the investor has to bear all of the costs. The level of resource commitment consistent with a joint venture will fall somewhere between these two extremes.

Where country risk is high, the investor might be well advised to limit its exposure to it by reducing its resource commitments and increasing its ability to exit from the market quickly without taking a substantial loss should the environment worsen. This suggests that, other things being equal, technology licensing and joint-ventures will be favored over wholly owned operations when country risk is high. In turn, this implies that higher country risk has a negative effect on the flow of wholly owned operations. The effect on joint-ventures and technology licensing is less clear-cut. For instance, consider technology licensing. On the one hand, we have argued above that the expected profits from technology licensing tend to reduce with risk, as do the incentives to employ this mode of international expansion. On the other hand, higher risk might force firms willing to exploit their technological assets internationally to opt for modes with reduced resource commitment. In other words, with higher levels of country risk, technology licensing becomes relatively more appealing than wholly owned investment. This latter effect increases the flow of licensed technology. The net result is ambiguous and technology licensing flows theoretically might either increase or decrease with country risk. This is therefore an empirical question that we will address with the data. What is unambiguous is that the coefficient of country risk on technology licensing flows must be smaller than the coefficient of country risk on flows of wholly owned operations. A similar argument could be put forward for joint-ventures that, as far as resource commitment, fall somewhere between wholly owned operations and technology licensing.

**Proposition 2:** *The impact of changes in country risk on the flow of wholly owned operations is larger than the impact on the flow of joint-ventures that, in turn, is larger than the impact on the flow of technology licensing.*

That multinational investment responds negatively to increasing degrees of country risk is, although correct, not too surprising in the light of historical evidence and industrial practice. Perhaps more interesting is the asymmetry between local and international investments in the response to changes in risk conditions. Indeed, all business transactions involve some degree of risk. However, when business transactions occur across international borders, they carry additional risks not present in domestic transactions. Anecdotal facts suggest that rises in country-specific risk have an immediate effect on international investment which is often considered more footloose and able to move to safer places. There are at least three possible arguments that can justify this position: First, local firms have a better understanding of country idiosyncrasies, so they are better equipped to manage risk. Second, their resource commitment might be substantially smaller than the one a foreign firm needs to undertake. Finally, their outside investment options are probably less interesting, so they would undertake riskier investments or ones with smaller expected benefits. We can therefore state the following:

**Proposition 3**: *Multinational investment is more responsive to changes in country risk than local investment.*

As far as IPRs are concerned the absolute effect of changes in the strength of protection on any form of international activity considered here is far from being theoretically clear-cut. On the one hand, stronger IPRs provide legal recourse against imitation by foreign firms and thus make more appealing the exploitation of technological assets abroad. This is known as the "market expansion effect". On the other hand, stronger IPRs also confer to the foreign firm more market power, which can be exploited by reducing the supply of products, by rising the price, and restricting the investment in the recipient country.  This is known as the “market power effect”. See Smith (2001) for further discussion. There is more consensus in the literature about the relative impact of stricter enforcement of IPRs on the use of different modes. The reference framework here is the so-called “eclectic paradigm” (Dunning, 1981). Such a paradigm suggests that, once a firm has decided to locate production abroad, the choice between different entry channels, most notably, foreign direct investment and licensing, depends of what Dunning labels “internalization advantages”. Applying the insights of the transaction cost theory (Williamson, 1991), this approach suggests that, absent significant contracting hazards, the ‘default’ low-cost governance mechanism is a simple contract. However, writing and executing a reliable contract for the use of technology requires adequate specification of property rights, monitoring and enforcement of contractual terms – any of which may be problematic. Stronger IPRs favor market-based transactions such as licensing because they force firms to better codify their knowledge in order to benefit from the protection of the intellectual property (Arora and Gambardella, 1994), reduce transaction costs by moderating the risk of opportunistic behavior by the licensees (Teece, 1986), and are a necessary condition for the rise of specialized technology suppliers, which in turn constitute a stimulus to market-based transactions in technology (Arora et al., 2001). However, two recent papers have defied this traditional wisdom. Arora and Ceccagnoli (2003) argue that on the one hand, stronger IPRs increase the efficiency of licensing contracts and thus the net surplus captured by the patent holder, but on the other hand, enhance the value of innovation and thus raise the opportunity cost of licensing. The net effect is therefore ambiguous. Maskus et al. (2003) go even further and claim that stricter enforcement of IPRs might reduce the use of licensing contracts in favor of wholly-owned investment in lower-technology industries.

## 4. Model Specification and Data

*4.1. Specification*

We assume that international activity through wholly owned operations, joint-ventures and licensing is a function of a set of variables which should account for the demand in a given country, of risk conditions, of the degree of IPRs protection and of some control parameters. Among the country variables we include income per capita, population and distance. These three variables are intended to capture respectively for relative endowments, market size and transportation costs. Markusen (1995) provides a survey of models that generate these core explanatory variables.

As control parameters, we have considered the country openness to trade and the country level of education.[5]

We apply the following specification:

$$TF_{ijt} = \alpha_0 INCOME_{it}^{\alpha_1} POP_{it}^{\alpha_2} DIST_i^{\alpha_3} R_{it}^{\alpha_4} IPR_{it}^{\alpha_5} OPEN_{it}^{\alpha_6} HUMAN_{it}^{\alpha_7} \varepsilon_{ijt} \tag{1}$$

where the subscript *i* denotes the country, the subscript *t* denotes the time period, and the subscript *j* denotes the mode (wholly owned, joint-venture or technology licensing). INCOME is the per capita income of the country, POP is the population, DIST is the weighted distance to capitals of world 20 major exporters, R is country risk, IPR is the degree of IPRs protection, OPEN is openness to trade, HUMAN is a measure of the country level of education, and $\varepsilon_{ijt}$ is a log normally distributed error term. $TF_{ijt}$ is the flow of wholly owned operations, joint-ventures and technology licensing, respectively.

Taking natural logs of equation (1) one obtains the following:

$$\begin{aligned} \ln(TF_{ijt}) = \alpha_0 + \alpha_1 \ln(INCOME_{it}) + \alpha_2 \ln(POP_{it}) + \alpha_3 \ln(DIST_i) + \alpha_4 \ln(R_{it}) + \alpha_5 \ln(IPR_{it}) + \\ \alpha_6 (OPEN_{it}) + \alpha_7 \ln(HUMAN_{it}) + \varepsilon_{ijt} \end{aligned} \tag{2}$$

Notice that we do not take the log of OPEN because this variable is a share.[6]

[5] We have experimented with several other variables, like barriers to trade of capital goods, financial openness, country's latitude, dummy for major non-oil exporter, dummy for major oil exporter, dummy for major oil producer, capital account restrictions, etc. Most of them showed an insignificant coefficient and the inclusion or exclusion did not affect the results reported here. For brevity, we do not report these results, which are available from the author upon request.

We expect positive parameters for INCOME and POP in all equations. The theoretical literature lacks consensus on whether transportation costs (DIST) and trade barriers (OPEN) increase or decrease international investments. For example, foreign direct investment or technology licensing might be a way to circumvent high transportation costs or barriers to exports (the so-called "tariff-jumping argument"; see Motta, 1992). However, models of complement behavior predict that conditions which decrease (increase) exports also decrease (increase) technology transfer modes which involve location in the foreign country (Smith, 2001). Finally, the sign of HUMAN is also ambiguous. The level of education might capture the "absorptive capacity" of the recipient country (Cohen and Levinthal, 1989). In this case, better educated workers available in the host country would facilitate both the creation of a wholly owned activity, the establishment of a joint-venture with a local partner and the transmission of technological knowledge to any potential licensee. However, higher level of education – better technological skills – might imply that local firms are better equipped for quickly imitating the technology of the foreign company. This means that the investor will try to protect its technology, reduce if possible any technological leakage, and ultimately restrict the amount of investment and technology transfer to the recipient country.

*4.2. Data*

Data on wholly owned operations, joint-ventures and technology licensing are obtained from Chemintell, a large commercial database on worldwide investments in chemical plants during the period 1981-1996. Chemintell is comprehensive, including almost the full population of chemical plants. For each chemical plant, the database reports both the name of the operating company and the name of the licensor when the technology used in the plant is bought from an unaffiliated source. In addition, it identifies when the property of a given plant is shared among different firms. In other words, using our database it is possible to track the entire set of wholly owned and co-owned plants in foreign countries and the whole flow of international technology licensing in

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[6] Both IPR and R are indexes which vary on a scale from 0 to 5 (with 5 meaning the highest level of IPRs protection) and from 0 to 100 (with 100 meaning the lowest level of country risk) respectively. For IPR we have used log(1+IPR). Since for R the minimum value is 4.7 we have simply taken the log.

the chemical industry during the period under study. The database also provides information about plant investment costs.

In order to identify the plants belonging to each mode of international activity, we have constructed a sample of large chemical firms. Such firms, given their large financial, managerial and organizational capabilities, were likely to have the option to decide the preferred mode of activity in any recipient country. Small chemical firms and, in particular, specialized engineering firms (SEFs), which are also active in international technology licensing, have to restrict their strategy space to whether they want to license or not. Since we would like to consider a framework where the mode of international activity is a decision variable for the investor, our sample is better suited for the type of analysis we are going to perform.

Our sample includes all chemical firms from developed countries (Western Europe, USA and Canada, and Japan) which had, by the year 1988, more than $1 billion in aggregate sales (the list of firms is obtained from Aftalion, 1991). Of this set of firms only 153 had at least one international plant (either as owner, co-owner or licensor) reported in Chemintell during the period under study. (See appendix.) Firms of our sample cover about 50% of all foreign direct investments and more than 30% of international technology licensing.

Table 1 shows the distribution of plants (number and value of the investment generated) by the firms of our sample across geographical areas during the period 1981-1996. Notice that technology licensing is the predominant mode in most third world areas (the only exception is South America). On the contrary, technology licensing accounts for less than 20% in most developed areas. Here, the exception is Japan where technology licensing accounts for about 40% of all international activity by the firms of our sample. [7]

[TABLE 1 ABOUT HERE]

There is also some variation across sub-subsectors. For instance, sub-sectors like Plastics and Industrial Gases show technology licensing as the predominant mode. On the other extreme, in Pharmaceuticals and Organic Chemicals wholly owned operations account for more than 90%

[7] There is also some variation across firms' nationality. US and European firms (globally taken) tend to behave similarly with about 25% of licensing activity. Japanese firms have a stronger attitude towards technology licensing which accounts for 60% of their international activity.

and 75% respectively. This suggests that there might be factors related to the technology which could be lost at a country-level aggregation. Some technologies might be more standardized, easier to transfer through contracts (Kogut and Zander, 1993) or there might exist more competition in the licensing market (see Arora and Fosfuri, 2003). All these factors favor a more extensive use of technology licensing. We will try to partially control for this technology-specific heterogeneity in our regressions in section 5.

We aggregate our data in four time periods: 1981-1983, 1984-1987, 1988-1991, 1992-1996.[8] Hence, we use the subindex *t=1,2,3,4* for each of the four periods respectively. There are three reasons for such aggregation. First, some country variables do not basically show variability from one year to another. Second, it typically takes several months or years from the decision to build a chemical plant to the completion of the investment. So, investment decisions tend to be correlated to long term rather than short term changes in country conditions. Third, in many countries (especially, the smaller ones) and for many years the flows of international activity would be zero.

Our dependent variable is the flow of international activity by the firms of our sample in a given country and in a given time period. As discussed above we distinguish between wholly owned operations, joint-ventures and technology licensing.

All our explanatory variables that have time variability are measured at the beginning of each time period. The only exception is our measure of IPRs which is only available for the year 1980, 1985, 1990 and 1995 (we have therefore assumed that these correspond respectively to our four periods).

We use a set of 75 countries for which we could collect comparable data on the characteristics described above. The list of countries is reported in the appendix. We have therefore a panel of 300 observations. Notice that the cross-time variability is quite modest for some country variables (like for instance IPR). For others, like R, is much more important.

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[8] There are respectively 1507, 1599, 2090 and 744 international plants by the firms of our sample in each period. The smaller number of plants in the last period is more likely to be due to misrepresentation in Chemintell rather than a reduction in the pace of international investment. Indeed, the shares of wholly owned investments, joint-ventures and technology licensing remain quite stable across all periods. As a robustness check we have excluded the last period from our analysis, and experimented with slightly different time periods. Results only change marginally.

For INCOME, POP and OPEN we have used the Penn world tables (which are available on-line at http://datacentre.chass.utoronto.ca/pwt/). DIST and HUMAN have been obtained from Barro-Lee (1994). (Available on-line at http://www.nuff.ox.ac.uk/Economics/Growth/barlee.htm.)
We measure the strength of IPRs using an index developed by Ginarte and Park (1997).[9] This index uses a coding scheme applied to national patent laws, where five categories are considered: extent of coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms and duration of protection. It has been extensively used in previous studies (see, among others, Smith, 2001; Oxley, 1999; Smarzynska, 2003). One limitation of this measure is that it is based on statutory protection, which might actually differ from the real protection (whether patent laws are enforced or not). We have also experimented with the index developed by Rapp and Rozek (1990). This index is only available for the mid 80s and reflects the conformity of national patent laws with minimum standards proposed by the US Chamber of Commerce. Both indexes are highly correlated and using one instead of the other does not affect any of the results.
As a proxy of country risk we use the Institutional Investor Credit Ratings (IICR). Institutional investor credit ratings are based on a survey of leading international bankers who are asked to rate each country on a scale from zero to 100 (where 100 represents maximum creditworthiness). Factors which are taken into consideration in this measure include the economic and political outlook, debt service, financial reserves, fiscal policy, access to capital market, trade balance and investments. To assess the sensitivity of the results we also use a weighted average of the political, economic and financial risks developed by the Political Risk Services' International Country Risk Guide (ICRG). This measure is only available starting from the mid 80s and it is highly correlated with the Institutional Investor Credit Ratings.[10] We find that our results are robust with respect to the choice of measure. Regressions are available from the author upon request. The Institutional Investor Credit Ratings have been used by Baven and Estrin (2000) to

[9] I would like to thank Professor Walter Park for kindly supplying the measure of patent protection used in this paper.
[10] The correlation (computed over 72 countries and 3 time periods) is above 0.9. Alternative measures of country risk, like the one developed by Euromoney and the Moody's ratings, are also highly correlated with the Institutional Investor Credit Ratings.

assess the impact of country risk on foreign direct investment in a set of transition economies. Other papers, like Wheeler and Mody (1991), have used more complex measures of country risk. We favor an approach in which the country risk is proxied by information actually available to firms at the time of the investment decision – the credit ratings – which can be purchased commercially.

Finally, we include dummy variables to control for time period fixed effects. For completeness, we also add a specification that includes country-specific random effects.

Table 4 summarizes our variables along with their sources, whereas Table 5 provides some basic descriptive statistics.

It is important to notice that some regressors tend to be correlated. In particular, the correlation between R, IPR, INCOME and HUMAN is always greater than 0.5. However, a condition number test does not suggest that multicollinearity is a serious issue (Greene, 1993).

Before turning to the empirical results, two important caveats about our explanatory variables are due here. First, whereas our dependent variables are measured at the country-industry level, all explanatory variables are measured at the aggregate country level. For instance, we are implicitly assuming that the level of education in the Chinese chemical industry corresponds to the level of education in China. Second, most of our explanatory variables are proxies for some underlying and typically unmeasurable phenomena. Some of these proxies might end up picking up different factors at once, and the interpretation of the estimates might turn difficult. As a conservative approach, we have therefore tried to stay as close as possible to the related literature in the choice of our proxies.

[TABLE 2 AND TABLE 3 ABOUT HERE]

## 5. Empirical results

Table 4 (model 1) reports the OLS estimation of equation (2) where the dependent variable is the logarithm of the sum of the investment generated by any of the three modes of international activity (wholly owned operations, joint-ventures and licensing) in country *i* and period *t*. In other words, we are proxing the flow of international activity with the value of the investments in the recipient economy (i.e. the costs of setting up the chemical plants). As a sensitive check, we have also performed our analysis using the number of plants rather than their value. Results hold unchanged.

TABLE 4 ABOUT HERE

INCOME and POP have a positive and significant effect on the total flow of international activity. DIST is positive, although not significant, suggesting that transportation costs favor location of production in distant countries vis-à-vis exporting. OPEN is positive and significant, meaning that more open countries tend to attract larger flows of international activity. HUMAN shows a negative coefficient, although barely significant. At face value, this implies that the threat of imitation outweighs the importance of absorptive capacity.[11]

The coefficient of R is positive and highly significant. This implies that increases in the country credit ratings, our proxy for country risk, generate a larger flow of international activity in the recipient economy. In dollar terms, this means that, in the average recipient country, a 10% increase in R with respect to the mean (about 46) generates an increment in the chemical investment driven by international activity of about $200 million per period.[12] IPR is positive, but not at all significant. At face value, this implies that IPRs protection does not play any role in conditioning the flow of international activity.

Since our sample includes mainly large firms, one could argue that these large corporations are better able to insulate themselves against changes in the strength of IPRs protection and that the effect of IPR is mostly on small firms. In table 5 we address this possibility by introducing a new dependent variable: $SEF_{it}$. $SEF_{it}$ is the investment in country *i* and period *t* generated by the licensing activity of specialized engineering firms (SEFs). SEFs are firms specialized in the design, engineering and sometimes licensing of chemical plants, but have no stakes in the product market. SEFs have usually a much smaller size than chemical firms. Especially compared to the firms of our sample, SEFs are definitely small firms. The results do not confirm our conjecture that small firms are more sensitive to the protection offered by the patent system, and IPR remains not significant.

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[11] One could also argue that foreign firms are less likely to enjoy a technological advantage in countries with higher levels of human capital, implying a negative relationship between HUMAN and the flow of international activity.

We have also performed a Tobit estimation (table 4, model 1a) of equation (2). Indeed, about 30% of the observations for our dependent variable show no investment at all in a given country and for a given time period. A Tobit estimation should account for the truncated (at zero) dependent variable. Qualitative results hold unchanged. Finally, we report the results of the random-effects GLS regression (table 4, model 1b), in which the individual error terms are randomly distributed across cross-sectional units. The Lagrange multiplier test and the Hausman test suggest that there are country-specific random effects and that these are uncorrelated with the exogenous variables.

TABLE 4 ABOUT HERE

As we discussed in section 3, the fact that IPR has no effect on international activity is not in contradiction with the theory. Indeed, stronger IPRs generate a market expansion effect and a market power effect. Since the former is positive and the latter is negative, the net effect is ambiguous. However, one can refine the theory a bit more. As suggested by Smith (2001), the risk of imitation is higher in countries with strong imitative abilities. Hence, one should expect that it is in these countries that the market expansion effect is stronger. Instead, in countries with poor imitative abilities an increase in IPRs protection would reinforce the market power of the investor and could possibly lead to a reduction in the flow of international activity.

In order to test this additional implication of the theory we follow Smith (2001)'s methodology and divide all our countries in two groups: countries with strong imitative abilities and countries with weak imitative abilities. We use the number of R&D scientists and engineers to define weak and strong imitative abilities. We construct two dummy variables: DWEAK, which takes the value of one if the country has weak imitative abilities (i.e. less than 500 scientists and engineers per million of population) and zero otherwise; DSTRONG, which takes the value of one if the country has strong imitative abilities (i.e. more than 500 scientists and engineers per million of population) and zero otherwise. Finally, we estimate an equation where these two dummies are multiplied by the variable IPR. Results are reported in table 4, model 2 for OLS, model 2a for Tobit and model 2b for GLS. As one can check, we do not find any evidence of a significant

[12] This is obviously a lower bound of the total effect since we only consider large investors from developed countries.

impact of changes in IPRs protection on the flow of international activity in countries with strong imitative abilities. Instead, we do find some weak evidence that countries with weak imitative abilities are recipient of more international activity when they implement a stricter enforcement of IPRs. This result is in contradiction with the theoretical argument illustrated above. We however take it with extreme caution because it not very robust and it disappears when we focus on each mode of international activity separately (see below).

TABLE 5 ABOUT HERE

We can now analyze the impact of our main explanatory variables on any single form of international activity, taking into consideration the simultaneous character of the three modes. The empirical method is to estimate equation (2) for the three modes by means of seemingly unrelated regression (SUR) techniques. Table 6, model 3a, reports the results of the SUR estimations of equation (2).

Overall the results seem to confirm the theoretical predictions discussed in section 3. INCOME and POP are always positive and significant in all equations. DIST is positive, but significant only for the WO and JV equations, and OPEN is only significant and positive in the WO equation. The latter finding might suggest that more open countries tend to attract larger flows of wholly owned operations. HUMAN is not significant in any equation, but in the LIC equation where it takes a negative sign. As far as it concerns country risk, the focus of this paper, R is positive and highly significant in all equations. The coefficient is considerably larger for the flow of wholly owned operations, which support our hypothesis 2. The coefficients of R in the LIC and the JV equations are roughly similar (although bigger in the JV equation), suggesting that these two modes of international activity are equally affected by country risk. IPR does not have a significant effect in any of the three modes analyzed in this paper. Table 6, model 3b, distinguishes between countries with strong imitative abilities and countries with weak imitative abilities. All coefficients remain basically unchanged. Our data do not seem to suggest that there exist a market expansion effect and a market power effect due to stronger IPRs. Indeed, the coefficient of IPR is never significant, not even at the 10% level of confidence.

[TABLE 6 ABOUT HERE]

Our final hypothesis has to do with the different responses to changes in country risk conditions that one should expect from international and domestic investment. We argued that international investment, especially by large corporations, is much more footloose and able to move to safer places. To contrast this hypothesis, we have constructed another dependent variable, $LOCAL_{it}$, which measures the investment in country *i* and period *t* by domestic enterprises. Table 5, model 1d and model 2d report the results of the estimation of this new equation. The coefficient of R is positive and significant. However its magnitude is much smaller than that of R in the WO equation (table 6, model 3a) where the dependent variable is the investment in wholly owned plants in country *i* and period *t* by the firms of our sample (large chemical corporations). Overall, we can argue that our results suggest that higher degrees of country risk have an obvious negative effect on total investment. However this effect is relatively stronger for investment by large multinational corporations, which tend to shift to modes with less resource commitment, and relatively smaller for investment by local firms.

One limitation of many studies that investigate the relationship between IPRs protection and international activity is that they aggregate flows of foreign direct investments and technology licensing across many diverse industries, some of which might not rely at all on the legal protection of intellectual property. By focusing on a single industry we clearly reduce this heterogeneity. Yet, the chemical industry is a vast sector that covers a myriad of different products from sophisticated drugs to fertilizers, from polymers to coal-based products. So far we have not tried to differentiate across different sub-sectors. However, there might be important differences. Indeed, for most process technologies in petrochemicals, basic plastics and industrial gases that had already matured by the 1980s patents were probably much less a concern during the period under study. By contrast, patents could be much more important for drugs, specialty chemicals and new polymers.[13]

To better control for systematic differences across different chemical sub-sectors we have split our dataset in different groups which are meant to include products with similar characteristics. We have run separate regressions for each group. Table 7 reports the results of our estimations for 5 main groups: Oil Refining, Petrochemicals, Plastics and Rubber, Gas (which includes Gas Handling, Air Separation, and Industrial Gases), and Organic Chemicals (which includes Explosives, Textile and Fibers, Food Products, and Pharmaceuticals). Our dependent variable is the logarithm of the sum of the investment generated by our three modes of international activity in any of the above mentioned groups. Notice that we have only three time periods since the sub-sector classification of Chemintell has changed after 1991. The sign of IPR is sometimes positive and sometimes negative, but almost never significant. It is positive and significant at the 10% level only in the Oil Refining equation. Contrary to what one could expect it is not significant in the Organic Chemical equation, where Pharmaceuticals is included.[14]

[13] Nevertheless, one should be aware that Chemintell only reports investment in plants, and it only deals with process technology. We do not have, for instance, product licensing, which is the major subject of transaction in pharmaceuticals.

[14] As an additional effort to control for sources of heterogeneity across different chemical products, we have also explored a range of discrete choice models where the dependent variable is the probability, at the plant level, to choose among our three modes of international expansion. As regressors we employed the same country variables used in this paper along with a set of controls for products' and firms' heterogeneity. Interesting enough, IPRs protection does not seem to be significant in conditioning the mode choice. We also find that in countries with better

[TABLE 7 ABOUT HERE]

## 6. Conclusions and Discussion

This paper has focused on country risk and IPRs protection as determinants of international activity by means of wholly owned operations, joint-ventures and licensing. We have shown that the whole flow of international activity into a recipient economy is negatively related to the level of country risk. Moreover, this effect holds for all modes considered in our analysis, namely wholly owned operations, joint-ventures and licensing. The relative effect is stronger for modes which involve greater commitment with the recipient country, such as wholly owned operations. Finally, we have shown that multinational investment is more responsive to risk conditions than domestic investment.

By contrast, after controlling for other country characteristics, we do not find evidence of a significant effect of IPRs protection on international activity.[15] Although surprising, this finding has some plausible justifications. First, our measure of IPRs protection reflects mainly statutory protection that might actually differ from the real protection (whether patent laws are enforced or not). Second, as reported by Cohen et al. (2000), patents are considered by firms as one of the less effective means to protect their intellectual property. This is especially true for process innovations, the ones we consider in the paper. So, in light of their findings, the fact that changes in patent protection do not affect international technology flows does not appear to be too surprising. Third, in a world where international treaties are becoming more enforced, a firm can sue for infringement in other jurisdictions (e.g. outside the host country). So, if the host IPRs regime is weak, the firm might still have recourse elsewhere (e.g. the WTO). Finally, even if IPRs protection affects neither the volume nor the composition of international activity, it might still affect the type of technology that is transferred. Firms might respond to lower levels of IPRs

risk conditions the probability that a foreign firm opts for a wholly owned plant is higher. For further details, see Fosfuri (2002).

[15] IPRs protection turns positive and significant if we omit other country characteristics. Notice that the correlation between IPR and the flow of wholly owned investments is about 0.3. However, IPR is not significantly correlated with joint-ventures and licensing.

protection by transferring older vintage technologies (Fosfuri, 2000). With our data, we are not able to investigate this possibility.

At face value, our results suggest that governments in less developed countries keen to attract foreign investment and technology should pay greater attention to the quality of the business environment and to investment conditions rather than offering more statutory protection to IPRs. Needless to say, improving country risk conditions is neither easy nor rapid. A statutory change in IPRs protection or the formal participation to an international IPRs agreement are much easier policies to implement. However, our paper shows they are not very effective.

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## APPENDIX

List of countries used in the empirical estimations: Algeria, Argentina, Australia, Austria, Bangladesh, Belgium, Bolivia, Brazil, Cameroon, Canada, Chile, Colombia, Congo, Costa Rica, Cyprus, Denmark, Ecuador, Egypt, El Salvador, Finland, France, Germany (West), Greece, Guatemala, Honduras, Hong Kong, Iceland, India, Indonesia, Iran, Ireland, Israel, Italy, Jamaica, Japan, Jordan, Kenya, Korea, Malawi, Malaysia, Mauritius, Mexico, Netherlands, New Zealand, Nicaragua, Norway, Pakistan, Panama, Papua New Guinea, Paraguay, Peru, Philippines, Portugal, Senegal, Sierra Leone, Singapore, South Africa, Spain, Sri Lanka, Sudan, Sweden, Switzerland, Syria, Thailand, Trinidad and Tobago, U.S.A., Uganda, Uruguay, Venezuela, Zambia, Zimbabwe.

Firms of our sample and their nationality: 3M (USA), Abbott (USA), AGA (SWE), Air Liquide (FRA), Air Products (USA), Akzo (NET), Allied-Signal (USA), American Home Products (USA), Amoco (USA), ARCO (USA), Aristech Chemical (USA), Asahi Chemical (JAP), Ashland Oil (USA), Atochem (FRA), Avon (USA), BASF (WGE), Baxter-Travenol (USA), Bayer (WGE), Beecham (UK), BF Goodrich (USA), BOC (UK), Boehringer Ingelheim (WGE), Boehringer Mannheim (WGE), Borden (USA), Borg Warner (USA), BP (UK), Bristol-Myers (USA), Cabot (USA), Ciba-Geigy (SWI), Colgate-Palmolive (USA), Cookson (UK), Courtaulds (UK), Cyanamid (USA), Chevron (USA), Daiichi (JAP), Dainippon (JAP), Degussa (WGE), Dow Chemical (USA), DSM (NET), Du Pont (USA), Dyno (NOR), Eastman Kodak (USA), Eisai (JAP), Elf Aquitaine (FRA), Eli Lilly (USA), EMC (FRA), EniChem (ITA), Ethyl Corp (USA), Exxon (USA), Ferro (USA), FMC (USA), Fujisawa Pharmaceutical (JAP), Gechem (BEL), General Electric (USA), Georgia Gulf (USA), Glaxo (UK), Goodyear (USA), Grace WR (USA), Henkel (WGE), Henley (USA), Hercules (USA), Hoechst (WGE), Hoffmann-LaRoche (SWI), Huls (WGE), Huntsman Chemical (USA), ICI (UK), IMC (USA), Japan Synthetic Rubber (JAP), Johnson & Jonson (USA), Kanebo (JAP), Kao (JAP), Kemira (FIN), Kuraray (JAP), Kyowa Hakko (JAP), Laporte (USA), Lonza (SWI), Lubrizol (USA), Lyondell Petrochemical (USA), Merck & Co (USA), Mitsubishi Chemical (JAP), Mitsubishi Gas Chemical (JAP), Mitsubishi Petrochemical (JAP), Mitsubishi Rayon (JAP), Mitsui Petrochemical (JAP), Mitsui Toatsu (JAP), Mobil (USA), Monsanto (USA), Montedison (ITA), Morton Norwich (USA), Nalco (USA), Neste (FIN), NL Chemicals (USA), Nobel Industries (SWE), Norsk Hydro (NOR), Nova (CAN), Occidental (USA), Olin (USA), ORKEM (FRA), Otsuka (JAP), P & G (USA), Pennwalt (USA), Perstorp (SWE), Petrofina (BEL), Pfizer (USA), Pharmacia (SWE), Phillips (USA), PPG (USA), Quantum (USA), Reckitt & Colman (UK), Repsol (SPA), Revlon (USA), Rhone-Poulenc (FRA), Rohm (WGE), Rohm & Haas (USA), Rorer Group (USA), Rutgerswerke (WGE), RWE (WGE), Sandoz (SWI), Sankyo (JAP), Sanofi (FRA), Schering (WGE), Shell (UK-NET), Shin-Etsu Chemical (JAP), Shionogi (JAP), Shiseido (JAP), Showa Denko (JAP), SmithKline (USA), Snia (ITA), Solvay (BEL), Squibb (USA), Sumitomo (JAP), Sun (USA), Syntex (USA), Taisho Pharmaceuticals (JAP), Takeda Chemical (JAP), Tanabe Seiyaku (JAP), Teijin (JAP), Tenneco (USA), Texaco (USA), Toray Industries (JAP), Toso (JAP), Toyobo (JAP), Ube (WGE), UCB (BEL), Unilever (UK-NET), Union Carbide (USA), Unitika (JAP), Unocal (USA), Upjohn (USA), Warner-Lambert (USA), Wellcome Foundation (UK), Witco (USA), Yamanouchi Pharmaceutical (JAP).

## FIGURES AND TABLES

**Table 1:** *Distribution of plants (number and value of investment) by geographic areas during the period 1981-1996 in the chemical industry (by the firms of our sample)*

| | | AF | EE | FE | JAP | ME | NA | SA | WE | Total |
|---|---|---|---|---|---|---|---|---|---|---|
| **WO** | *Number* | 75 | 15 | 562 | 120 | 27 | 988 | 316 | 1195 | 3298 |
| | *Value* | 8.0 | 1.0 | 53.9 | 5.2 | 3.5 | 71.1 | 32.2 | 63.4 | 238.3 |
| | *Share* | 34 | 5 | 38 | 39 | 9 | 82 | 57 | 73 | 55 |
| **JV** | *Number* | 19 | 52 | 303 | 72 | 92 | 46 | 57 | 105 | 746 |
| | *Value* | 2.0 | 3.5 | 29.1 | 3.1 | 12.1 | 3.3 | 5.8 | 5.6 | 64.5 |
| | *Share* | 9 | 19 | 20 | 23 | 32 | 4 | 10 | 6 | 13 |
| **LIC** | *Number* | 127 | 207 | 627 | 119 | 167 | 165 | 179 | 327 | 1918 |
| | *Value* | 13.6 | 14.1 | 60.2 | 5.1 | 21.9 | 11.9 | 18.3 | 17.3 | 162.4 |
| | *Share* | 57 | 76 | 42 | 38 | 59 | 14 | 33 | 21 | 32 |
| **Total** | *Number* | 221 | 274 | 1492 | 311 | 286 | 1199 | 552 | 1627 | 5962 |
| | *Value* | 23.6 | 18.6 | 143.2 | 13.4 | 37.5 | 86.3 | 56.3 | 86.3 | 465.2 |

*Note*: Value in billions of US dollars. AF = Africa; EE = Eastern Europe; FE = Far East (including Australia); JAP = Japan; ME = Middle East; NA = North America; SA = South America; WE = Western Europe.

**Table 2:** *Variables and sources*

| Variable | Description | Source |
|---|---|---|
| $ALL_{it}$ | Investment in country i and period t generated by the international activity of our sample firms (in millions of US dollars) | Chemintell (1996) |
| $WO_{it}$ | Investment in country i and period t generated by wholly owned operations of our sample firms (in millions of US dollars) | Chemintell (1996) |
| $JV_{it}$ | Investment in country i and period t generated by joint-ventures of our sample firms (in millions of US dollars) | Chemintell (1996) |
| $LIC_{it}$ | Investment in country i and period t generated by technology licensing of our sample firms (in millions of US dollars) | Chemintell (1996) |
| $SEF_{it}$ | Investment in country i and period t generated by technology licensing of specialized engineering firms (in millions of US dollars) | Chemintell (1996) |
| $LOCAL_{it}$ | Investment in country i and period t by local firms (in millions of US dollars) | Chemintell (1996) |
| $INCOME_{it}$ | (Real) income per capita in country i at the beginning of period t (in US dollars) | Penn World Table |
| $POP_{it}$ | Population of country i at the beginning of period t (in thousands) | Penn World Table |
| $DIST_{i}$ | Weighted distance of country i's capital to capitals of 20 major exporters (in kilometers) | Barro and Lee (1994) |
| $HUMAN_{it}$ | Averaged schooling years in the total population over age 25 in country i at the beginning of period t | Barro and Lee (1994) |
| $OPEN_{it}$ | (Exports + Imports)/GDP at current international prices in country i at the beginning of period t | Penn World Table |
| $IPR_{it}$ | Strength of patent protection in country i at period t. This is an index which accounts for the extent of patent coverage, membership in international patent agreements, provisions for loss of protection, enforcement mechanisms and duration of protection | Park and Ginarte (1997) |
| $R_{it}$ | Global index of risk in country i at the beginning of period t | Institutional Investor Credit Rating |
| $R2_{it}$ | Composite index of risk (political, financial and economic) in country i at the beginning of period t | Erb, Harvey, and Viskanta (1996) |
| $DWEAK_{i}$ | Dummy variable that takes the value of one if the country has less than 500 scientists and engineers per million of population and zero otherwise | Statistical Yearbook (UNESCO) |
| $DSTRONG_{i}$ | Dummy variable that takes the value of one if the country has more than 500 scientists and engineers per million of population and zero otherwise | Statistical Yearbook (UNESCO) |
| Time fixed effects | Dummy variables for the following time periods: 1981-1983, 1984-1987, 1988-1991, 1992-1996 | Chemintell (1996) |

**Table 3:** *Descriptive statistics (n = 300)*

| Variable | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|
| $ALL_{it}$ | 1375.0 | 2598.3 | 0 | 16402 |
| $WO_{it}$ | 783.5 | 1882.7 | 0 | 13924 |
| $JV_{it}$ | 153.9 | 376.5 | 0 | 2772 |
| $LIC_{it}$ | 437.7 | 998.1 | 0 | 12996 |
| $SEF_{it}$ | 617.7 | 1109.5 | 0 | 7310 |
| $LOCAL_{it}$ | 3331.5 | 7729.6 | 0 | 68600 |
| $INCOME_{it}$ | 6730 | 5641 | 439 | 24518 |
| $POP_{it}$ | 54390 | 153428 | 231 | 1164951 |
| $DIST_{i}$ | 5662 | 2562 | 1267 | 11500 |
| $HUMAN_{it}$ | 5.3 | 2.7 | 0.9 | 12 |
| $OPEN_{it}$ | 65.8 | 51.0 | 12.9 | 427.9 |
| $IPR_{it}$ | 2.67 | 0.94 | 0 | 4.86 |
| $R_{it}$ | 46.5 | 25.8 | 4.7 | 98.3 |
| $R2_{it}$ | 64.2* | 16.5 | 25.5 | 94.0 |
| $DWEAK_{i}$ | 0.427 | 0.495 | 0 | 1 |
| $DSTRONG_{i}$ | 0.573 | 0.495 | 0 | 1 |

* Only available for 72 countries and 3 time periods.

**Table 4:** *OLS and Tobit estimations: $ALL_{it}$*

| | OLS: $ALL_{it}$ | | TOBIT: $ALL_{it}$ | | GLS random effects | |
|---|---|---|---|---|---|---|
| | **Model 1** | **Model 2** | **Model 1a** | **Model 2a** | **Model 1b** | **Model 2b** |
| Constant | $-27.48^{***}$ | $-30.010^{***}$ | $-33.73^{***}$ | $-37.18^{***}$ | $-14.34^{*}$ | $-14.49^{*}$ |
| $INCOME_{it}$ | $1.144^{***}$ | $1.430^{***}$ | $1.499^{***}$ | $1.776^{***}$ | 0.402 | 0.369 |
| $POP_{it}$ | $1.209^{***}$ | $1.270^{***}$ | $1.405^{***}$ | $1.574^{***}$ | $1.017^{***}$ | $1.014^{***}$ |
| $DIST_{i}$ | 0.444 | 0.267 | 0.416 | 0.202 | 0.081 | 0.154 |
| $HUMAN_{it}$ | $-0.605^{*}$ | -0.295 | $-0.852^{**}$ | -0.453 | -0.552 | -0.628 |
| $OPEN_{it}$ | $0.008^{***}$ | $0.009^{***}$ | $0.009^{**}$ | $0.011^{***}$ | 0.006 | 0.006 |
| $IPR_{it}$ | 0.384 | | 0.591 | | -0.130 | |
| DWEAK* $IPR_{it}$ | | -0.012 | | 0.125 | | 0.005 |
| DSTRONG *$IPR_{it}$ | | $0.902^{*}$ | | $1.278^{*}$ | | -0.250 |
| $R_{it}$ | $1.509^{***}$ | $1.538^{***}$ | $2.024^{***}$ | $2.043^{***}$ | $2.138^{***}$ | $2.085^{***}$ |
| | | | | | | |
| Number of obs. | 300 | 300 | 300 | 300 | 300 | 300 |
| Left-censored | | | 85 | 85 | | |
| Adjusted R2 | 0.571 | 0.580 | | | | |
| Log likelihood | | | -590.21 | -587.12 | | |
| Wald chi2 | | | | | 144.23 | 148.04 |

*Note*: *10%, **5%, ***1%. The regressions include dummies for time fixed effects.

**Table 5:** *OLS estimations: $SEF_{it}$ and $LOCAL_{it}$*

| | $SEF_{it}$ | | $LOCAL_{it}$ | |
|---|---|---|---|---|
| | **OLS** | **Tobit** | **OLS** | **Tobit** |
| Constant | -28.91*** | -17.37*** | -20.52*** | -20.77*** |
| $INCOME_{it}$ | 0.946*** | 1.348*** | 0.748*** | 0.793** |
| $POP_{it}$ | 1.279*** | 1.765*** | 1.103*** | 1.205*** |
| $DIST_{i}$ | 0.636** | 0.699* | -0.069 | -0.157 |
| $HUMAN_{it}$ | -0.264 | -0.494 | -0.170 | -0.191 |
| $OPEN_{it}$ | 0.004 | 0.006 | -0.003 | 0.003 |
| $IPR_{it}$ | -0.312 | -0.059 | -0.123 | -0.079 |
| $R_{it}$ | 0.800** | 1.065** | 0.820** | 0.948** |
| | | | | |
| Number of obs. | 300 | 300 | 300 | 300 |
| Left-censored | | 102 | | 47 |
| Adjusted R2 | 0.536 | | 0.553 | |
| Log likelihood | | -565.07 | | -619.57 |

*Note*: *10%, **5%, ***1%. The regressions include dummies for time fixed effects.

**Table 6:** *SUR estimations*

| Model 3a | | | |
|---|---|---|---|
| | **$WO_{ij}$** | **$JV_{ij}$** | **$LIC_{ij}$** |
| Constant | -37.447*** | -35.273*** | -24.856*** |
| $INCOME_{it}$ | 0.795*** | 0.609** | 1.201*** |
| $POP_{it}$ | 0.973*** | 0.828*** | 1.159*** |
| $DIST_i$ | 0.974** | 1.213*** | 0.433 |
| $HUMAN_{it}$ | 0.205 | 0.092 | -0.640* |
| $OPEN_{it}$ | 0.006** | 0.003 | 0.002 |
| $IPR_{it}$ | 0.243 | -0.275 | -0.428 |
| $R_{it}$ | 1.960*** | 1.183*** | 0.945*** |
| | | | |
| Number of obs. | 300 | 300 | 300 |
| R2 | 0.554 | 0.432 | 0.496 |
| **Model 3b** | | | |
| | **$WO_{ij}$** | **$JV_{ij}$** | **$LIC_{ij}$** |
| Constant | -39.406*** | -36.463*** | -27.423*** |
| $INCOME_{it}$ | 1.017*** | 0.743*** | 1.491*** |
| $POP_{it}$ | 1.020*** | 0.857*** | 1.220*** |
| $DIST_i$ | 0.838*** | 1.130*** | 0.253 |
| $HUMAN_{it}$ | 0.445 | 0.237 | -0.326 |
| $OPEN_{it}$ | 0.007** | 0.003 | 0.003 |
| $DWEAK*IPR_{it}$ | -0.064 | -0.461 | -0.829 |
| $DSTRONG*IPR_{it}$ | 0.644 | -0.031 | 0.099 |
| $R_{it}$ | 1.983*** | 1.196** | 0.974*** |
| | | | |
| Number of obs. | 300 | 300 | 300 |
| R2 | 0.560 | 0.436 | 0.507 |

*Note*: *10%, **5%, ***1%. The regressions include dummies for time fixed effects.

**Table 7:** *OLS estimations at the sub-sector level*

| | **Oil Refining** | **Petrochemicals** | **Plastics and Rubber** | **Gas** | **Organic Chemicals** |
|---|---|---|---|---|---|
| Constant | $-23.37^{***}$ | $-36.77^{***}$ | $-35.57^{***}$ | $-27.99^{***}$ | $-21.76^{***}$ |
| $INCOME_{it}$ | $1.068^{***}$ | $1.272^{***}$ | $1.433^{***}$ | $0.990^{***}$ | 0.207 |
| $POP_{it}$ | $0.891^{***}$ | $1.240^{***}$ | $1.328^{***}$ | $0.854^{**}$ | $1.116^{***}$ |
| $DIST_{i}$ | 0.318 | $0.876^{***}$ | $0.713^{**}$ | $0.626^{*}$ | 0.324 |
| $HUMAN_{it}$ | -0.301 | 0.111 | 0.010 | -0.038 | 0.048 |
| $OPEN_{it}$ | $0.009^{**}$ | 0.005 | $0.011^{***}$ | $0.008^{**}$ | $0.008^{**}$ |
| $IPR_{it}$ | $1.013^{*}$ | -0.288 | -0.256 | 0.832 | 0.016 |
| $R_{it}$ | $0.806^{**}$ | $0.820^{**}$ | $0.667^{**}$ | $0.876^{**}$ | $1.642^{***}$ |
| | | | | | |
| Number of obs. | 225 | 225 | 225 | 225 | 225 |
| | | | | | |
| Adjusted R2 | 0.396 | 0.530 | 0.592 | 0.431 | 0.532 |

*Note*: *10%, **5%, ***1%. The regressions include dummies for time fixed effects.