Intracompany Governance and Innovation*

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Abstract

This paper examines the relation between ownership, corporate form, and innovation for a cross-section of private and publicly traded innovating firms in the US and 15 European countries. A striking novel observation emerges from our analysis: while most innovating firms in the US are publicly traded conglomerates, a substantial fraction of innovation is concentrated in private firms and in business groups in continental European countries. We find virtually no variation across US industries in the corporate form of innovating firms, but a substantial variation across industries in continental European countries, where business groups tend to be concentrated in industries with a slower and more fundamental innovation cycle and where intellectual protection of innovators seems to be of paramount importance. Our findings suggest that innovative companies choose the corporate form most conducive to R&D, as predicted by the *Coasian view* of how firms form. This is especially true in Europe, where there are fewer regulatory hurdles to the formation of business groups and hybrid corporate forms. It is less the case in the US, where conglomerates are generally favored.

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1. Introduction

Which corporate forms are most propitious to innovation? Is it standalone firms financed by Venture Capital (VC)? Is it conglomerate incubators, or looser business-group structures combining multiple partly-owned affiliates? While GE, Hewlett-Packard, IBM, DuPont or 3M are often mentioned as examples of highly innovative conglomerate firms in the U.S., there have also been many prominent examples of VC-backed standalones in recent years, such as Amazon, Netscape, or Google. Although VC-backed innovation has been less important in Europe, innovative activity in conglomerates such as Phillips or Nokia is highly visible, and business-groups in the vein of Ericsson, Zeiss, Alstom and Novartis are also renowned innovators.

Economists and business scholars following Williamson (1975, 1985) and Chandler (1962, 1977, 1990) have pointed to the advantages of centrally managed organizations in managing and funding R&D, and in marketing and distributing new products. More recently, corporate finance scholarship has pointed to the benefits of internal capital markets of conglomerates in lowering the cost of capital for R&D (Gertner, Scharfstein and Stein, 1994 and Stein, 1997) while at the same time emphasizing the *dark side* of internal capital markets, in terms of reduced financial discipline for poorly performing investments (Scharfstein and Stein, 2000). Seru (2007) in particular, finds evidence consistent with this dark side of internal capital markets: publicly traded U.S. conglomerates with above-average reallocation of funds across divisions are less productive innovators than comparable stand-alone firms. Similarly, Guedj and Scharfstein (2004) compare clinical trials in the biopharmaceutical industry and find that big pharmaceuticals firms engaged in cancer research tend to initiate too many studies but are quicker to terminate unpromising research than smaller (stand-alone) biotech firms. In contrast, Belenzon and Berkovitz (2010) find European evidence that innovation tends to be concentrated in business-groups and that business-group affiliates tend to engage in more innovation than comparable stand-alone firms.

This paper studies the link between innovation and corporate organization across nations and industries by systematically investigating the organization of inventive activity in R&D intensive countries. We propose a model in which stand-alone firms, conglomerates and business groups have distinctive governance characteristics: stand-alone firms offer the highest form of intellectual property rights protection but also suffer from the greatest external financing constraints. Conglomerates have the weakest financing constraints for internal divisions thanks to internal capital markets; they also benefit from better winner-picking by corporate headquarters, but they offer the weakest property-rights protections. Business groups offer better intellectual property rights protections and also provide financing through a business group internal capital market, but their greater decentralization comes at the cost of less well coordinated R&D and also worse winner-picking. At the same time, business groups are less tax efficient due to their exposure to inter-company dividend taxes, and they are more vulnerable to tunneling distortions.

In light of these complex governance tradeoffs across organizational forms, the studies by Seru (2007), Guedj and Scharfstein (2004), and Belenzon and Berkovitz (2010) do not necessarily offer contradictory evidence and more systematic evidence is required to have a better understanding on how governance interacts with innovation. In this paper we offer a more complete picture of the link between governance and innovation by comparing first the distributions of organizational forms of innovating firms across 15 European countries and the United States, and second the distribution of organizational forms across industries in each of these countries. While other studies have explored variations in the prevalence of business groups across countries, virtually nothing is known on how organizational forms of innovating firms differ across industries (and also across countries).

As is well known, business groups are rare in the U.S. (and somewhat rare in the U.K.), but they are omnipresent elsewhere in the world. They have been associated with poor minority investor protection and inefficient rent extraction by controlling shareholders (see Johnson, La Porta, Lopez-de-Silanes, and Shleifer, 2000, and Bertrand, Mehta, and Mullainathan, 2002). Their prevalence is consequently seen by these authors as stemming from poor legal investor protections. Consistent with this literature, we also allow for inefficient rent extraction in business groups. However, following Almeida and Wolfenzon (2006) our model also allows for business group strengths in terms of cheaper internal R&D funding. We add to this important benefit, two other critical benefits: first, greater intellectual property protections for innovators in business groups relative to conglomerates, and second a lower stigma of failure relative to stand-alone firms.

An important basic premise of our analysis is that innovating firms tend to set up their corporate governance to implement an efficient environment to foster innovation. Thus, when the observed choice of corporate form is a conglomerate or a business group we assume that this is the revealed preferred choice of organization. In other words, a basic premise of our analysis is a *Coasian perspective* on firm organization. Thus, to the extent that a particular corporate form is especially well suited for innovative activities, we expect this corporate form to be more prevalent among innovative firms in a given industry than among non-innovating firms.

We distinguish between four types of organizational form: standalones, corporate headquarters - also referred to as conglomerates, wholly-owned affiliates, and partly-owned affiliates - also referred to as business groups. Standalones are firms that have no equity ties to other firms. Corporate headquarters control a group of firms and are located at the group apex. Wholly-owned affiliates are subsidiaries that are wholly-owned by headquarters, and partly-owned affiliates are firms that have minority shareholders in addition to their controlling corporate ultimate owner (headquarters).

We base our analysis on a comprehensive data-set of both private and publicly traded American and European firms, and match all corporate patents granted by the United States Patent and Trademark Office (USPTO) and the European Patent Office (EPO) to these firms. We also single out firms that publish their research in academic journals. We have thus identified about 64.000 firms that hold at least one patent from the EPO or USPTO, or have published at least one scientific article in a science journal. Of these 64.000 firms, about 60% are American, 11% German, 8% British, 4% French, and 5% are Italian. We matched 776.030 USPTO, 532.894 EPO patents, and 166.586 scientific publications. 73% of USPTO patents and 33% of EPO patents are held by American corporation. Germany appears to be the most innovative European country while holding 12% and 28% of USPTO and EPO patents, respectively. For scientific publications, about 63% of the articles are published by U.S. corporations, 13% German, and 5% French, and 4% British.

Several surprising findings emerge from our analysis. First, while the overall distribution of citations-weighted USPTO patents by ownership structure in the whole sample is 19% standalones, 61% headquarters, and 21% affiliates, in the U.S. this distribution is skewed towards standalones and headquarters, with 19% and 66% respectively of patents falling in these categories, and only 14% of patents being held by affiliates. In Europe, on the other hand, 53% of the patents are held by affiliates, and 9% and 38% respectively are held by standalones and headquarters. A similar pattern emerges for EPO patents and scientific publications. There is also a wide variation in organizational form across European countries. While Germany appears to resemble the U.S. in terms of concentration of innovation in headquarters (58%), French and Italian firms are clearly skewed towards affiliates, with only 9% and 8% respectively of their patents being held by headquarters.

Second, we distinguish between affiliates that are wholly-owned by their parent company and affiliates that have minority shareholders. The presence of minority shareholders in an affiliate company establishes a separation between the affiliate and its parent company in terms of retained profits, patent holdings, and resource reallocation. Remarkably, in the U.S. less than one percent of patents are held by partly-owned affiliates, while in France and Italy about 20% of innovation takes place in affiliates with minority shareholders. Great Britain has a unique structure, with 55% of British patents held by affiliates (as compared to only 14% of U.S. patents), but effectively all of these affiliates are wholly-owned subsidiaries.

Third, the U.S. distribution of innovating firms is also heavily skewed towards publicly traded firms. Indeed, the fraction of patents held by publicly traded American corporations is above 60%, while this fraction is only about 30% in Europe. In some large European countries this picture is even more extreme. In France and Italy only 6% and 3% of patents, respectively are held by publicly traded firms.

Fourth, we find a substantial variation in organization structure across industries. Affiliates, especially partly-owned, tend to be concentrated in industries where innovation takes a longer time to complete, is more uncertain, but has a higher payoff when it succeeds. These innovative activities may be more vulnerable to hold-up problems and require greater intellectual property rights protection for the innovator. In Pharmaceuticals, close to 30% of the patents in continental Europe are held by partly-owned affiliates (interestingly, this picture is completely different in the U.S. and Great Britain, where only 1% of patents are held by partly-owned affiliates). In contrast, conglomerates are more prevalent in industries with rapid, incremental, innovations, where the ability of conglomerates to identify the relevant innovation and to quickly redeploy assets may give this organizational form an edge over business groups. Thus, in the telecommunications sector, partly-owned affiliates are rare, with only 3% of continental European patents and less than 1% of American and British patents held by partly-owned affiliates.[1]

There may, of course, be other reasons besides governance and finance why we see this cross-industry pattern in organizational form. For example, organizational capacities in marketing new products, and in adapting quickly to new economic conditions may also explain this cross-industry variation. Thus, our findings of high centralization of inventive activity in industries with rapidly changing economic environment is consistent with and reinforces the organization flexibility theories (Daft, 1998). Governance and flexibility are inherently related, as stronger governance builds upon decentralized decision making and greater autonomy of

[1] Our findings on business group prevalence are consistent with previous works on alliance formation in the US. Robinson and Stuart (2007) argue that corporate alliances in the biotechnology industry are designed to overcome governance problems in large US conglomerates, while Robinson (2007) points to the benefits of corporate alliances in providing better incentives for long shot R&D projects. Interestingly, alliances in the US are concentrated in industries where business groups are most prevalent in Europe. This is consistent with the view that alliance formation allows US firms to mimic the governance structure of European business groups.

business unit managers. Similarly, flexibility in terms of frequent resource reallocation may affect ex-ante incentives by inducing divisional managers to invest in more short-term projects. Intellectual property rights and organizational form are also complements with respect to the commercialization of inventions. In industries where commercialization is achieved at a more aggregate level, by combining several inter-related inventions, the owner of a patent to a single invention may be more vulnerable to hold-up problems by the organization. Put differently, high-powered incentives in the form of equity stakes in a partly-owned subsidiary is likely to be less effective in such industries. We would then expect the centralized conglomerate organizational form to emerge in these industries and to see other incentive mechanisms in place than intellectual property rights to induce R&D.

We note finally that our findings are broadly consistent with a *Coasian view* on firm organization form, which is to say that firms *choose* the organizational form that is best suited to fostering innovative activities. The alternative, dominant, view in the literature on business groups is that then organization form is chosen by *entrenched* managers, or controlling shareholders, to suit their best interests at the expense of minority shareholders and overall firm efficiency. By this latter view it is not obvious that one should see any systematic difference in organization form in a given country across industries. Strong industry variation is especially observed in Europe, where there are fewer regulatory hurdles to the formation of business groups and hybrid corporate forms. It is not the case in the U.S., where conglomerates are the norm.

The remainder of the paper is organized as follows. Section 2 presents the theoretical framework, section 3 overviews the data, section 4 reports the main empirical findings and section 5 concludes.

2. A Simple Model

We set up a model with at least two business units, which can be stand-alone entities, divisions in a conglomerate firm, or units linked in a business group, with one parent company owning a controlling block in a separately incorporated firm.

1. Technological Assumptions

There are $N \geq 2$ business units with liquid assets $W_i \geq 0$ and a new *R&D* project. The R&D project has fixed costs $f > 0$ at date 1 and a probability of success $\theta(a)$ at date 2. The probability of success depends on how well the project is managed, or more formally, on which action $a \in \{0, 1\}$ the project's manager chooses. The project's value to the business unit conditional on success is given by $v(a) > 0$. A successful R&D project may also generate spillovers to other business units worth $s(a) \geq 0$. When the research is unsuccessful (with probability $(1 - \theta(a))$) it yields no financial return.

The project brings expected private benefits or costs to the managerial team undertaking it. The benefits may come in the form of improved human capital and knowledge, better future career prospects, enhanced reputation in the event of success. The costs may be the stigma of failure when the research is not successful. Without loss of generality we normalize the net benefits arising from simply undertaking the project to zero. We denote by $b > 0$ the private benefits that come with success and by $\psi > 0$ the private costs associated with the stigma of failure.

We shall assume that:

$$b\theta_1 - \psi(1 - \theta_1) < b\theta_0 - \psi(1 - \theta_0),$$

so that the expected net private benefits to the manager are highest when the manager chooses $a = 0$. Note that the latter inequality reduces to

$$(b + \psi)(\theta_0 - \theta_1) > 0,$$

and therefore holds if and only if $\Delta\theta \equiv \theta_1 - \theta_0 < 0$. We also assume that

$$(v_1 + b)\theta_1 - \psi(1 - \theta_1) - f > 0 > (v_0 + b)\theta_0 - \psi(1 - \theta_0) - f$$

These inequalities together with $\Delta\theta < 0$ mean that the innovative activity is equivalent to taking a higher risk, higher expected payoff actions. In other words, R&D activities are high risk, but also high reward activities. The above inequalities also mean that the R&D activity is worth undertaking if and only if the manager can be induced to choose the high risk, high reward, action $a = 1$.

To simplify the analysis we also restrict attention to parameter values such that $b\theta_1 \leq \psi(1-\theta_1)$. The manager's expected private costs from the stigma of failure when he chooses $a = 1$ are then greater than the private benefits from a successful innovation. Under this assumption the manager has to receive some form of financial incentive to be willing to undertake the risky innovative activity.

2. Governance Assumptions and Firm boundaries

We distinguish between three main types of firms: standalones, conglomerates (with wholly-owned affiliates) and business-groups with affiliates owned in part by minority shareholders.

A *standalone firm* is essentially a firm with a single business unit. Such a firm is run by a manager with an equity stake sufficient to align incentives and is monitored by a large blockholder, venture capitalist (VC), or creditor, who plays the role of an *active monitor* as in Holmstrom and Tirole (1994). A standalone firm is viable only if it is able to raise sufficient funds to finance the research, while preserving the manager's incentives to conduct the research and the monitor's incentive to monitor.

We assume that only a fraction η of the firm's value $v(a)$ can be pledged to raise external funds. The parameter $\eta \in (0, 1)$ represents the fraction of R&D cash-flow that is *capitalizable* by the firm. It provides a simple measure of the financial development of a country. The higher is η the more financially developed a country is. We assume that capital markets are perfectly competitive for the pledgeable part of firm value and for simplicity we normalize the equilibrium required risk-adjusted return to zero.

Following Holmstrom and Tirole (1994) we also assume that the *timing* of the contractual relation between investors in the firm, the VC monitor, and the entrepreneur is as follows:

1. following an injection of funds in the firm by investors, the monitor moves first by choosing

whether to engage in costly monitoring or not;

2. the R&D project manager moves second by choosing whether to take action $a = 0$ or $a = 1$, having observed whether the active monitor is monitoring or not;

3. the R&D project either succeeds or fails;

4. if it succeeds the proceeds from the project are distributed to all investors and the manager.

Suppose that the active monitor decides to monitor the manager and incurs the monitoring cost $m > 0$. Then as in Holmstrom and Tirole (1994), we assume that the manager's net private benefits are lowered by a fraction $(1 - \lambda)$, where $\lambda < 1$.

The manager must be incentivized to choose $a = 1$. If his financial stake in the project, α, is large enough he will choose $a = 1$ even though his private benefits are higher for $a = 0$. Formally, the manager's stake α must be such that the following incentive compatibility constraint holds:

$$(\alpha v_1 + \lambda b)\theta_1 - \lambda\psi(1 - \theta_1) \geq (\alpha v_0 + \lambda b)\theta_0 - \lambda\psi(1 - \theta_0)$$

or

$$\alpha\Delta V + \Delta\theta\lambda(b + \psi) \geq 0.$$

where $\Delta V \equiv (v_1\theta_1 - v_0\theta_0)$ and $\Delta\theta = \theta_1 - \theta_0$. [2]

If there is no monitoring, on the other hand, the incentive compatibility constraint is: [3]

$$\alpha\Delta V + \Delta\theta(b + \psi) \geq 0.$$

Monitoring is beneficial if two conditions are satisfied.

First, it must be the case that the firm cannot get sufficient financing in the absence of monitoring. That is, the firm should not be able to invest in R&D, by using all its internal funds W_i and raising $(f - W_i)$ from outside investors, while at the same time granting sufficient

[2] Note that under our assumptions ΔV is strictly positive and $\Delta\theta$ is strictly negative.

[3] Since $\Delta\theta < 0$ the incentive constraint is clearly harder to satisfy with no monitoring than under monitoring.

financial incentives to the entrepreneur to choose $a = 1$ even though there is no monitoring. Therefore, a first condition is that:

$$(1-\alpha)\eta v_1\theta_1 < f - W_i$$

for any α such that

$$\alpha\Delta V + \Delta\theta(b+\psi) \geq 0,$$

or

$$[1 + \frac{\Delta\theta(b+\psi)}{\Delta V}]\eta v_1\theta_1 < f - W_i.$$

Second, the firm must be able to get financing when there is monitoring. The active monitor has an incentive to monitor and incur the monitoring cost m as long as his stake β in the firm's profit is large enough that $\beta\eta\Delta V \geq m$. In exchange for the stake $\beta = \frac{m}{\eta\Delta V}$, which just ensures that he will monitor, the active monitor is willing to invest an amount equal to his expected equilibrium net return: $\beta\eta v_1\theta_1 - m$. Therefore, the standalone firm is viable under monitoring if

$$(1-\alpha-\beta)\eta v_1\theta_1 \geq f - W_i - \beta\eta v_1\theta_1 + m,$$

or, substituting for α and β if:

$$(1 + \frac{\Delta\theta\lambda(b+\psi)}{\Delta V} - \frac{m}{\eta\Delta V})\eta v_1\theta_1 \geq f - W_i - m(\frac{v_1\theta_1}{\Delta V} - 1).$$

Rearranging, this condition reduces to:

$$[1 + \frac{\Delta\theta\lambda(b+\psi)}{\Delta V}]\eta v_1\theta_1 \geq f - W_i + m.$$

Clearly, for η large enough, and m and λ small enough this condition will be satisfied given our assumption that

$$v_1\theta_1 > f.$$

A *conglomerate firm* operates $n \geq 2$ business units that are wholly-owned subsidiaries. It has corporate headquarters that make investment and R&D decisions for all divisions. A key feature of conglomerate firms is that profits of subsidiaries are channeled to headquarters, who report consolidated earnings to the firm's shareholders. Divisional managers typically cannot be rewarded based on their division's profit, and their incentive pay-component is generally based only on conglomerate profits and stock price. Moreover, divisional managers don't own the intellectual property they create, unless they negotiate a contract which explicitly gives them the right to any innovation they create. [4]

On the other hand, divisional managers may be closely monitored by headquarters. Another advantage of undertaking research in a conglomerate is that failure can be hidden to some extent inside the firm, so that there is a lower stigma of failure. Conglomerates also develop *winner picking* skills, and benefit from R&D spillovers on other divisions.

For our formal analysis we assume that conglomerate firms are composed of only two divisions, A and B. We also simplify the governance of conglomerate firms to the CEO's role in picking winner R&D projects and to the CEO's active monitoring of division managers. We model winner picking by assuming that a project selected by headquarters has a probability of success $\rho\theta(a)$, where $\rho \geq 1$. We model CEO monitoring by letting the CEO monitor division managers $j = A, B$ at cost μ and thereby lowering division managers' private benefits by a fraction $(1 - \lambda)$. If the divisional manager's research is successful, however, it is owned by the firm. Thus, division managers have lower powered incentives to pursue R&D in conglomerates. [5] In our model, a divisional manager can only extract a small share γ of the direct value of the innovation by, for example, threatening to leave and pursue his research at another firm. Thus, the divisional manager's incentive constraint for choosing action $a = 1$ in a conglomerate is:

$$(\gamma v_1 + \lambda b)\rho\theta_1 + (1 - \rho\theta_1)\lambda\psi \geq (\gamma v_0 + \lambda b)\rho\theta_0 + (1 - \rho\theta_0)\lambda\psi,$$

or

$$\gamma\Delta V + \Delta\theta\lambda(b + \psi) \geq 0.$$

[4] Such contracts are not common and even when a contract grants intellectual property rights to the innovator it is difficult to enforce.

[5] Divisional managers may get a share of conglomerate profits, but due to moral hazard in teams problems, they will have lower powered incentives than if they received a share of their own division's profits. For simplicity, we ignore the financial incentives from shares in conglomerate profits.

Finally, conglomerates have the financing advantage of drawing on the sum of liquid assets of both divisions, $(W_A + W_B)$, to fund a division's R&D project. To summarize, in our model a conglomerate picks the most promising R&D project from the divisions, thus ensuring a probability of success of $\rho\theta_1$ in equilibrium. It finances the project entirely with its own funds $(W_A + W_B)$ and it incurs monitoring costs μ. Thus, the conglomerate's expected return is given by:

$$(1-\gamma)v_1\rho\theta_1 - f - \mu + W_A + W_B$$

provided that it can induce the divisional manager whose R&D project is picked to choose action $a = 1$. Should γ be so low that

$$\gamma < \frac{\Delta\theta\lambda(b+\psi)}{\Delta V}$$

then the division manager will choose $a = 0$, in which case we assume that the conglomerate will not pick any R&D projects.

A *business-group* of $n \geq 2$ firms is similar to a conglomerate firm. It has a controlling hub akin to corporate headquarters and multiple divisions. The key differences with a conglomerate are that: *i)* the business units are not wholly owned subsidiaries, but rather are independently incorporated companies controlled by the group's majority shareholders through a controlling stake; *ii)* earnings of business units are not consolidated, and ownership of intellectual property remains with the innovating business unit; *iii)* R&D project selection is more decentralized, so that the group's hub plays less of a winner picking role. The group mainly plays the role of an internal capital market to fund R&D investments.

We denote by φ the ownership share of the group and $(1-\varphi)$ the share owned by minority shareholders. An important potential source of inefficiency in business groups is the separation of ownership and control of business units. This separation can give rise to inefficient diversion of business unit earnings by the controlling shareholders. We model this diversion as in Almeida and Wolfenzon (2006) by allowing the controlling shareholders to "divert" d of earnings from a unit in which they have a stake φ at a deadweight cost of

$$k(d) = \frac{1}{2}\kappa d^2.$$

Group owners then choose d to maximize:

$$\varphi(v - d) + d - \frac{1}{2}\kappa d^2,$$

where ν denotes the business unit's earnings. As is easily established, the optimal amount of diversion and the deadweight cost of diversion are then respectively:

$$d(\varphi, \kappa) = \frac{1-\varphi}{\kappa} \text{ and } k(d(\varphi, \kappa)) = \frac{(1-\varphi)^2}{2\kappa}.$$

The earnings retained in the firm–$(v - \frac{1-\varphi}{\kappa})$–can be shared between the division manager and all the owners. Thus division managers can be incentivized as in standalones based on the non-diverted earnings. Moreover, the business unit manager's private benefits can be reduced through monitoring by the group's controlling owners.

As the literature on business groups has emphasized, the diversion of earnings by controlling shareholders reduces the efficiency of business groups relative to stand-alone firms or conglomerates. [6] The pervasiveness of business groups around the world (with the important exceptions of the U.S. and Great Britain) suggests, however, that there is also a countervailing efficiency improving role of business groups. [7] We argue that the efficiency gain of business groups is due to the stronger intellectual protection given to innovators in business units affiliated to business groups, who can retain (partial) ownership of their patents.

To summarize, business groups combine the R&D incentive benefits of stand-alone firms with the internal capital market benefits of conglomerates. Given equal R&D incentives, however,

[6] There can also be diversion of funds from conglomerates with separation of ownership and control. For simplicity we ignore this form of diversion in our model.

[7] While, some commentators simply explain the existence of business groups as an inefficient outcome caused by managerial entrenchment, others point to the value adding role of business groups as providers of a substitute source of funding for investment in environments where external capital markets are inefficient due to inadequate investor protection. Thus, the prevalence of business groups in emerging market countries is seen as a necessary but transitory consequence of the underdevelopment of securities markets in these countries. However, as our evidence highlights, business groups are also prevalent in advanced countries, with developed securities markets and strong investor protections. Moreover, as we show, these groups tend to be both very competitive and innovative.

business groups are less efficient than conglomerates, as they involve both inefficient diversion of funds and less effective winner-picking.

3.Assumptions on external legal environment

Besides η (the fraction of the value of innovations that is capitalizable) we introduce three other key parameters to capture the external legal environment: τ an intercompany dividend tax, γ the R&D project manager's bargaining power, and ψ the stigma cost of failure. As we argue in the next section, the main comparative advantages of the U.S. relative to the EU are that U.S. securities markets free up a higher η and γ. Moreover, U.S. entrepreneurial culture and bankruptcy laws also result in a lower ψ. Against these comparative advantages the EU's main advantage is a lower τ.

3. Model Analysis

We divide the model analysis into two parts. We begin by considering the main tradeoffs in organizational form keeping the external legal environment fixed. In a second step we do a EU-US comparative analysis by analyzing how changes in the parameters (η, τ, ψ) affect the equilibrium distribution of R&D across organizational forms.

3.1. Main tradeoffs within a given legal environment

We consider in turn the choice between undertaking R&D in a stand-alone unit or inside a conglomerate firm, the pros and cons of a business-group and a conglomerate structure, and finally the choice between stand-alone and affiliation to a business-group.

3.1.1. Stand-alone firm vs. Conglomerate: the costs and benefits of internal capital markets

Consider the funding of R&D projects in a conglomerate with two business units, A and B. To facilitate comparisons with a stand-alone firm we assume that only one of the two units has a potential research project, say division A. We also assume that the conglomerate has sufficient internal funds or capital to be able to fund the project without raising external funds, $(W_A + W_B) \geq f$. A conglomerate has lower costs of monitoring and greater winner-picking skills, so that it will be more efficient at R&D as long as it can provide adequate incentives to choose action $a = 1$ to its divisional managers. Therefore, R&D is organized in a conglomerate whenever divisional managers have sufficient incentives to choose action $a = 1$. That is, whenever γ is large enough that:

$$\gamma + \frac{\Delta\theta\lambda(b+\psi)}{\Delta V} \geq 0.$$

If γ is too small then R&D may be organized in a standalone firm provided that enough external funding can be obtained, or:

$$[1 + \frac{\Delta\theta\lambda(b+\psi)}{\Delta V}]\eta v_1\theta_1 \geq f - W_i + m.$$

In Figure 1 below we describe the parameter regions for which R&D takes place in respectively a standalone firm (SA) and a conglomerate (CL) in $(\Delta V, f - W_i + m)$ space. The function $h(\Delta V)$ is given by

$$h(\Delta V) \equiv [1 + \frac{\Delta\theta\lambda(b+\psi)}{\Delta V}]\eta v_1\theta_1$$

and the vertical line $\Delta V_{\#}$ is

$$\Delta V_{\#} = -\frac{\Delta\theta\lambda(b+\psi)}{\gamma}.$$

For all values of $\Delta V \geq \Delta V_{\#}$ the incentive constraint for $a = 1$ in conglomerates is satisfied and R&D is organized in a conglomerate. For $\Delta V < \Delta V_{\#}$, R&D is not efficient in a conglomerate, but it may be sustainable in a standalone firm provided that the parameter values for $(\Delta V, f - W_i + m)$ lie in the area (SA); that is, provided that $(f - W_i + m) \geq m$ lies below $h(\Delta V)$. In situations where the hold-up problem is so severe that R&D projects cannot be undertaken efficiently in a conglomerate, innovators may still be able to undertake their R&D project in a standalone firm provided that the external financing needs of the R&D project

$(f - W_i)$ are sufficiently low, and/or the costs of monitoring the innovator (m) are sufficiently low.

Simple comparative statics results can be inferred from Figure 1. In particular, any upward shift in the function $h(\Delta V)$ and any rightward shift in $\Delta V_{\#}$ will increase the region of R&D in standalones relative to conglomerates. In other words, an increase in $\eta v_1 \theta_1$ makes R&D easier to sustain in standalones and an increase in $|\Delta\theta|$ makes it harder to sustain in conglomerates. This suggests that high-risk-high-payoff R&D (with high $|\Delta\theta|$ and high $\eta v_1 \theta_1$ is more likely to be found in standalones than conglomerates.

Insert Figure 1 here

The role of Venture Capital (VC) in the US is mainly to target these types of innovations. As we explain in the next section, we believe that in the EU in contrast to the US the role of VCs is partly filled by business-groups. The reason is that in the EU the capitalization of R&D (as measured by η) is lower than in the US. Moreover the stigma of failure ψ is also higher.

3.1.2. Conglomerate vs. Business Group: internal capital markets, the cost of diversion and the intercompany dividend tax and intellectual property rights protection

Business groups can provide better protection of intellectual property rights of its business units than conglomerates but they are exposed to inefficient diversion of funds by their controlling owners. Suppose that unit A is combined in a group with unit B, and as before suppose that $(W_A + W_B) \geq f$. Let φ_A denote the group's ownership share in affiliate A and suppose that φ_A is large enough that the group has adequate incentives to actively monitor the manager of affiliate A. Recall that for every \$1 generated by affiliate A a fraction $\frac{1-\varphi_A}{\kappa}$ is diverted to the group and a fraction $\left(1 - \frac{1-\varphi_A}{\kappa}\right)$ is retained by the affiliate. Therefore, if the manager of A is to effectively undertake an R&D project (i.e. to choose $a = 1$) his stake must be at least equal to

$$\alpha = -\frac{\Delta\theta\lambda(b + \psi)}{\Delta V \left(1 - \frac{1-\varphi_A}{\kappa}\right)}.$$

Setting $\alpha = 1 - \varphi_A$, its maximum possible value, it is then straightforward to see that a business group with equilibrium diversion of funds $\frac{1-\varphi_A}{\kappa}$ is able to foster efficient R&D in unit A as long as $\Delta V \geq \Delta V_*$ given by: [8]

$$\Delta V_* = -\frac{\Delta\theta\lambda(b+\psi)}{(1-\varphi_A)\left(1-\frac{1-\varphi_A}{\kappa}\right)}.$$

Since business-groups involve costs which are not incurred by conglomerates they will only be the chosen organization form for R&D activities when adequate R&D incentives cannot be provided in conglomerates, or when $\Delta V \in (\Delta V_*, \Delta V_{\#})$.

But, even for these parameter values business groups may not be the chosen organizational form if the tax burden in terms of intercompany dividend taxation exceeds the benefit from greater R&D incentives. Intercompany dividend taxes amount to

$$\tau\varphi_A\left[\left(1-\frac{1-\varphi_A}{\kappa}\right)v_1 - f\right]$$

in our model. Indeed, the reported (and undiverted) revenues by affiliate A in the event of a successful innovation are given by $\left(1-\frac{1-\varphi_A}{\kappa}\right)v_1$. Therefore the realized profits are $\left(1-\frac{1-\varphi_A}{\kappa}\right)v_1 - f$. The business-group obtains a share φ_A of realized profits on which it pays a marginal intercompany dividend tax of τ. If the tax rate τ is too high it may not be worthwhile for the group to fund the R&D project in affiliate A. [9]

3.1.3. Business Group vs. Stand-alone: diversion costs and the benefits of internal capital markets

The main advantage of Business groups over standalones is that they are able to tap the internal capital of the entire group to fund new R&D projects. Given that business groups also involve

[8] Note that the manager's financial stake generally has to be higher than for a stand-alone, as a fraction $\left(\frac{1-\varphi_A}{\kappa}\right)$ of the financial value of the innovation is siphoned off by the group. But note also that the higher is the marginal cost of diversion κ, the less funds are diverted and therefore the lower is the manager's financial stake necessary to incentivize him to do research. Similarly and somewhat paradoxically, the higher is φ_A–the group's stake in affiliate A–the lower is the manager's financial stake necessary to incentivize him.

[9] Intercompany dividend taxes are not the only cost of setting up a partially integrated business group. Other tax rules, company registration rules, accounting rules concerning the consolidation of accounts and regulations limiting the flexibility of holding company structures may result in other costs. Thus, for example in the US the Public Utility Holdings Company Act of 1935 has substantially limited the scope for business groups in the energy sector.

diversion costs, R&D will only be undertaken in a business group if it is not possible to fund R&D in a standalone using costly external financing. This is illustrated in Figure 2 below.

Insert Figure 2 here

Again, simple comparative statics results can be seen from this figure: an upward shift in $h(\Delta V)$ increases the region of R&D in standalones and reduces the region in business groups (BG). There is R&D in business groups for $\Delta V \geq \Delta V_*$, only when it is not feasible in standalones. When there is a rightward shift in ΔV_*, R&D in business groups is less likely. Such a rightward shift may occur if κ is lower, so that there is more potential for diversion of funds. We therefore expect the share of R&D taking place in business-groups across European countries to be inversely related to the ease of diversion allowed by the corporate legal environment in each country.

3.1.4. Business Group vs. Stand-alone and Conglomerates: the benefits of internal capital markets diversion costs and intellectual property rights protection

We can combine the comparison of the three organizational forms into a single figure (Figure 3) and obtain the following broad comparative statics insights for fixed country parameters (η, ψ, τ).

Conglomerates will be a higher fraction of innovating firms when there is a leftward shift in $\Delta V_{\#}$. This shift may be due to either a higher γ or a lower $\Delta\theta$. One may expect industries with many, incremental, innovations to have both higher γ (through greater implicit incentives) and lower $\Delta\theta$. These industries are therefore more likely to be dominated by conglomerates. Their ability to quickly identify the relevant innovation and to quickly redeploy assets gives these organizational forms an edge over business groups and standalones. Moreover, in these industries conglomerates can credibly offer adequate incentives for in house R&D without granting formal ownership rights to the innovators.

Business groups are likely to be more prevalent in industries with a slower and more fundamental innovation cycle, where $\Delta\theta$ is higher (and γ lower). These organizational forms may not be the most efficient in picking winners but they are able to provide better intellectual ownership protection. To the extent that it is harder to divert funds (κ is higher) we should also see more innovating business groups, as ΔV_* is then lower. But a more efficient VC sector with lower monitoring costs (m) and/or lower costs of external funds will tend to reduce the dominance of business groups in these industries.

In general, we expect industry variation in the share of business groups among innovating firms across industries. However, we also expect this variation to be smaller in countries where the absolute advantage of one organizational form due to the country's regulations and laws is stronger.

Insert Figure 3 here

3.2. Main EU-US comparative predictions

Business groups have one major comparative advantage in continental European countries relative to the US: the general absence of an intercompany dividend tax. In addition, there is more of a stigma of failure in these European countries and financial markets are also somewhat less developed. For all these reasons, we expect R&D to be concentrated in higher proportion in business-groups relative to conglomerates and standalones in continental Europe than in the US. For the same reasons, we expect to find more R&D activity in publicly traded firms in the US than in the EU. These simple predictions are indeed borne out in the data as we show below.

4. Data

Our paper combines data from several sources: (1) firm and ownership data from **Amadeus** for European firms and from **Icarus** for American firms (both are provided by Bureau van Dijk), (2) information on patents from the United States Patent and Trademark Office (**USPTO**) and the European Patent Office (**EPO**), and (3) scientific publications from **Thomson Web of Knowledge**.

The Bureau van Dijk data is collected from various government sources in Europe. The main advantage of the data is their comprehensive cross-sectional coverage. For practically all firms in Europe and the U.S. we have information on their name and address, which we use in matching patents and scientific publications. However, these data have several limitations. First, in some European countries reporting of financial information is not mandatory for very small firms. For example, in Great Britain companies with less than 10 employees do not have to report financial information, such as sales and number of employees, in their annual reports. In France, on the other hand, all firms are obliged to report financial information. To mitigate this selection issue, we make no restrictions on the availability of financial items when including firms in our sample. Moreover, as our goal in this paper is to map inventive activity across organization form, it is not likely that the observed pattern would be driven by very small firms as the vast majority of patents are generated by large corporation. Second, central to our analysis is ownership information. In case ownership coverage vary systematically across countries, our findings may be biased. A-priory there is no reason to suspect that the ownership data is systematically biased. The ownership data is collected by a large international team of researchers and analysts that track, in addition to company reports, news and other public sources that provide ownership information. There are about 4 million firms in our data for which ownership information is available (these firms are included in ownership algorithm which is described below). However, there still may be some noise in our ownership data, especially for smaller firms, that may potentially bias our findings. To mitigate the potential measurement bias, we hand-collect ownership information on the top 20 companies for the major countries in our sample from financial reports and various public sources. We confirm that the data for these firms as reported by Bureau van Dijk is accurate, and that the same patterns we observe for the whole sample also holds for the restricted sample of large corporations. We also randomly check the information provided by Bureau van Dijk for numerous firms by directly accessing Company Houses in different countries as well as firm websites. Here as well we find very few discrepancies between the Bureau van Dijk data and the information that is reported in the different public sources we have examined.

4.1. Ownership

The Amadeus and Icarus data sets contain detailed information on direct ownership links between firms. We sort firms into four different categories based on their ownership structure: (i) standalones, (ii) headquarters, (iii) wholly-owned affiliates, and (iv) partly-owned affiliates.

A firm is categorized as a standalone if it has no equity ties to any other firm, and as a headquarters if it stands at the apex of a group of firms, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has both a parent-company controlling-shareholder and other minority shareholders. In the context of our model there is not much of a difference between a division of a conglomerate and a wholly-owned subsidiary.[10][11] There is a significant difference, however, between a division of a conglomerate and a partly-owned affiliate. Some of the affiliated firms in our sample, especially those that are wholly-owned, have no substantial economic activity and exist only for tax or accounting reasons. To avoid including economically insignificant firms that may influence the classification of firms as standalones and headquarters, we classify a firm as headquarters only if it has affiliates with real economic activity (in determining whether a firm controls other firms, we include both innovating and non-innovating firms). Thus, when classifying firms as headquarters, we exclude affiliates that generate less than $1 million in annual sales and employ less than 20 employees. Moreover, as the goal of this paper is to explore stable organizational forms, we exclude groups that are held by private equity and other investment institutions, as well as joint ventures.

[10] The case of wholly-owned affiliates can be potentially studied in the context of delegated authority, lying somewhere between no control (the employee case) and full control (the owner case). Quoting Oliver Hart (1995): "If firm A buys firm B and converts it into a wholly owned subsidiary, then it is often argued that the managers of firm B have more control and authority ('independence') than if firm A merges with firm B."

[11] Future research should extend our model to allow for informal delegation. Examples include: (i) centralized personnel management and its career-oriented administration make it difficult for the HQs to differentiate and isolate internal divisions in terms of pay, status, transfers, and so on. (ii) Subsidiaries are apparently treated differently from internal divisions. There are differences in terms of pay, status, and future career prospects between internal divisions and subsidiaries. (iii) Both employees and communities tend to accept differential treatments across legal boundaries.

As our model highlights minority shareholders play a central legal and governance role in protecting intellectual property owned by the affiliate firm. Groups establish an intra-company separation of ownership and control. This separation puts minority shareholders at risk of expropriation by majority shareholders, as the literature on business groups has emphasized. However, European Corporate Group Law imposes strict provisions on the reallocation of resources between group affiliates, which provide an intellectual property protection to researchers in affiliate firms. These provisions practically make the group affiliate independent in terms of its assets, patents, and retained profits. Unlike for group affiliates, researchers in conglomerate divisions do not have the same legal protection of intellectual property. Conglomerate headquarters can freely reallocate assets, funds and IP rights across different units with no legal restriction or threat of litigation by division stakeholders. Our comparative analysis focuses mostly on the relative prevalence of partly-owned business group affiliates, conglomerates, and standalones.

To fully characterize the ownership structure of firms in our sample, we use ownership links information for private and public American and European firms from the ownership section of the 2008 version of Icarus and Amadeus. To ensure that all ownership links truly represent control, we make the following assumptions:

1. for private subsidiaries, we keep only links where the shareholder has at least 50% of the voting rights, and

2. for public firms we keep only links where the shareholder has at least 20% of the voting rights. These two assumptions leave us with close to one million ownership links.[12]

3. to infer group structure from these links we use the algorithm developed and described in Belenzon and Berkovitz (2010). This algorithm constructs corporate ownership-chains

[12] Erring on the side of caution, we define control of a private firm as owning at least 50% of the firm's voting rights (excluding non-voting shares). Following previous literature on public firms (La Porta et al. 1999; Faccio and Lang, 2002; and others), which have a more dispersed ownership, we set the threshold for control of a public firm at 20%. All our results are robust to different numbers for these thresholds.

and groups together firms controlled by the same ultimate owner. Appendix A.1 provides more information about the ownership algorithm and group construction.[13]

4.2. Patents and Scientific Publications

To create a firm-level measure of innovation, we examine patent based indicators of technological advances by firms.[14] Our patents data builds upon Belenzon and Berkovitz (2010) who matched EPO and USPTO patents to the complete set of Amadeus firms. We extend their data to include also American firms by matching patents to Icarus, and update the European matching to include patents granted up to 2007. For the USPTO, our source of information is an updated version of the NBER file which covers the period 1975-2007.[15] For the EPO, our main information source is the 2007 publication of the PATSTAT database, which is the standard source for European patent data and is published by the OECD. This database contains all European patent applications and granted patents from the beginning of the EPO system in 1978 to 2007. For each USPTO and EPO patent document we have information on the name of the firm to which the patent is assigned as well as the firm's address. We match the name and the address fields from the patent document to the name and address fields in Amadeus and Icarus. To control for patent quality, we weight patents by the number of citations they receive, excluding self-citations (that is, a citation from one patent to a predecessor patent that

[13] We conduct several robustness tests to check the sensitivity of our findings to ownership assumptions. For control assumptions, the same pattern of results continues to hold for ownership thresholds of 40% and 25% for private firms, and 10% for public firms. Furthermore, we construct business group structures using the algorithm developed by Almeida, Yong Park, Subrahmanyam, and Wolfenzon, 2007 (AYPSW). The advantage of AYPSW over our algorithm is that it better deals with cases of cross-holdings (e.g., firm A owns 50% of firm B, and firm B owns 50% of firm A), however, our algorithm better handles very large ownership datasets and is more robust to missing ownership links. For reasons of computational power we are not able to run the AYPSW algorithm on our full set of firms. Although restricting the ownership sample is problematic, the general pattern that emerges highly resembles the one generated by our own algorithm. While cross-holdings are prevalent in East-Asian countries, where the AYPSW algorithm was first implemented, we find that cross-holdings are very rare in Europe. Only 0.01% of the ownership chains our algorithm generates are associated with some form of cross-holdings. In the vast majority of cases where cross-holdings are evident, they do not involve the ultimate owner, thus, the classification of firms to the different organizational form categories is not affected.

[14] We use patents data to measure innovative activity, because we do not have direct information on R&D expenditures for private firms. For a discussion on the use of patents data as a measure of inventive activity, see Griliches (1990).

[15] The NBER patents file is described by Hall, Jaffe and Trajtenberg (2001) and Jaffe and Trajtenberg (2002).

is held by the same citing firm), in a period of five years after they are granted[16]. We control for cohort and technology area effects using the weighting scheme proposed by Trajtenberg (1990). For each patent, we divide the number of citations it receives by the average number of citations received by all patents granted at the same year and classified under the same three-digit technology class.[17][18]

Another innovation indicator is scientific publications in academic journals (Cockburn and Henderson, 1998). We look at scientific publications for two main reasons. First, not all inventions are patentable, and even if they are, patents can vary substantially in quality. Scientific publications, on the other hand, are not subject to the patentability selection problem, and they are generally regarded as indicators of high-quality research. Second, while patents typically represent more *directed* and *incremental* research, scientific publications tend to be the result of more basic and risky research (Belenzon and Patacconi, 2009). To measure the publication activity of our sample firms, we develop a data set of firm scientific articles. The world's largest source of information on scientific publications is Thomson's ISI Web of Knowledge, which includes publication records on hundreds of international journals in the 'hard' sciences. Each publication has an address field which contains the authors' affiliation. We match all firms (patenting and non-patenting) by name to the complete ISI database using the author

[16] Using a short citations lag allows us to avoid truncation problems that are associated with comparing patents of different ages. However, we examine the sensitivity of our results to longer citation lags, and find practically the same pattern of results when using citation lags of five, ten, and twenty years.

[17] We make no restrictions on the availability of accounting information for our sample firms. That is, every firm that was matched to the patent or publications data sets is included in our analysis. While the coverage of accounting information is likely to vary across countries, especially for very small firms, the coverage of names and addresses is rather constant across countries regardless of firm size. The general pattern of results continues to hold when we exclude firms for which we have no accounting information, or firms with less than 20 employees (this threshold tends to reduce differences in coverage across countries).

[18] Although we do not exclude firms from our sample if they do not report financial information, some interesting observations emerge from examining only firms for which financial information is available. Standalone firms tend to be substantially smaller than conglomerates and partly-owned affiliates, while conglomerates and partly-owned affiliates do not differ much on size. The average standalone firm has 177 employees (a median of 20), and about $100 million in annual sales (a median of $8.3 million). The average conglomerate has 3.650 employees (a median of 136), and $918 million in annual sales (a median of $14.3 million). The average partly-owned affiliate has 2.400 employees (a median of 214), and about $1 billion (a median of $65 million). Comparing conglomerates to partly owned-affiliates, the different in mean size (annual sales) is not significant (a *t-stat* of -0.482).

affiliation name and address fields.

5. Empirical findings

5.1. Cross-country Comparison

Several striking findings emerge from our cross-country analysis, as summarized in tables 1-3. First, while the overall distribution of citations-weighted USPTO patents by ownership structure in the whole sample is 19% for standalones, 61% for corporate headquarters, and 21% for affiliates, in the United States this distribution is skewed towards standalones and corporate headquarters, with 19% and 66% respectively of patents falling in these categories, and only 14% of patents held by affiliates. In Europe, on the other hand, 53% of the patents are held by affiliates, and 9% and 38% respectively are held by standalones and corporate headquarters. A similar pattern emerges for EPO patents and scientific publications. There is also a wide variation in organizational form across European countries. While Germany appears to resemble the U.S. in terms of concentration of innovation in corporate headquarters (58%), French and Italian firms are clearly skewed towards affiliates, with only 9% and 8% respectively of their patents held by corporate headquarters.

Second, we distinguish between affiliates that are wholly-owned by their parent company and affiliates that have unrelated minority shareholders. The presence of minority shareholders in an affiliate company establishes a separation between the affiliate and its parent company in terms of retained profits, patent holdings, and resource reallocation. Remarkably, in the United States less than one percent of patents are held by partly-owned affiliates, while in France and Italy about 20% of innovation takes place in affiliates with minority shareholder ownership. Great Britain has a somewhat unique structure, with 55% of British patents held by affiliates (as compared to only 14% of U.S. patents), but with nearly all of these affiliates being wholly-owned subsidiaries.[19][20]

Third, the U.S. distribution of innovating firms is also heavily skewed towards publicly traded firms (table 2). Indeed, the fraction of patents held by publicly traded American corporations is above 60%, while this fraction is only about 30% in Europe. In some large European countries this picture is even more extreme: in France and Italy only 6% and 3% of patents, respectively are held by publicly traded firms. Interestingly, however, relative to sales innovation is disproportionately concentrated in publicly traded firms both in Europe and the U.S. (columns 7-9). In the U.S., 35% of sales of all firms (innovating and non-innovating) are concentrated in publicly traded firms, as compared to 60% of all U.S. patents held in publicly traded firms. A similar pattern holds for European firms, where 20% of sales are concentrated in publicly listed firms and about 30% of European patents are held by these firms.

Another interesting observation relates to differences in patent assignment in conglomerates and business-groups. U.S. conglomerates usually assign patents to headquarters or to special central intellectual property management divisions, and not to the division where patent was generated. For example, IBM assigns almost all patents its divisions generate to its New-York headquarters (as indicated by the assignee name on the patent records)[21]. Other examples of

[19] Our model is too simple to make a distinction between divisions of a conglomerate and wholly-owned subsidiaries. A richer framework could make a meaningful distinction by introducing relational contracts (see e.g. MacLeod and Malcomson, 1989; Levin, 2003, and chapter 10 in Bolton and Dewatripont, 2005). The idea is that by creating legally independent firms within a corporation, an organization may be able to gain flexibility by supporting separate relational contracts for different sets of employees. We leave the exploration of this idea to future research.

[20] We supplement our cross-sectional analysis by examining ownership changes for a sample of innovating firms that were acquired by an American or European corporation during the period 1997-2007. Consistent with our previous control assumptions, we include deals where the acquired shares exceed 50% for private firms and 20% for public firms. The M&A sample includes 2.478 firms (where 1,236 are American, 389 British, 199 French, and 293 German), which hold 25.068 USPTO and 28.399 EPO patents. We distinguish between wholly-owned and partly-owned acquisitions. The pattern of results is consistent with the cross-sectional observations. While in the U.S. effectively all acquisitions are wholly-owned, in Europe, about half of the acquired (citations-weighted) patents are by partly-owned acquisitions. We also examine the distribution of organizational form of newly established firms. We observe a very similar pattern of results for firms that were founded between 1997 and 2007. In the U.S. and Great Britain, about 1% of these firms are founded as partly-owned affiliates, as compared to 11% in continental Europe (in France, 27% of the firms are incorporated as partly-owned affiliates).

[21] Interestingly, the pattern of scientific publications assignments is different than that of patent assignments. Where all IBM's patents are assigned to headquarters, academic publications are always assigned to IBM's research centers, mostly in Yorktown Heights New-York, Austin Texas and LA.

large conglomerates that adopt a central patent management structure include General Electric (where 21,830 out of 22,348 of GE's patents are assigned to its Global Research Center division in New-York), and 3M (where 10,640 out of the 10,806 of 3M's patents are assigned to its headquarters, and the remaining patents are assigned to the wholly-owned IP management subsidiary 3M Innovative Property).

In contrast, business-groups have a decentralized patent assignment. We hypothesize that the presence of minority shareholders makes it difficult to simply transfer IP assets from the inventing to the controlling firm. In France, for example, L'Oreal holds 3,135 USPTO patents, out of a total number of 4,882 patents assigned to the whole Nestle group. Assigning L'Oreal's patents to Nestle would be considered an expropriation of the rights of minority shareholders of L'Oreal. The transfer of patents to the controlling entity requires some form of valuation and compensation of shareholders of the originating firm. This is likely to be a difficult transaction, which is why patents mostly remain with the originating firm.

Table 3 further highlights the differences in the distribution of patents by ownership type across countries. Panel A describes the top 20 American innovating firms. Leading the list is IBM with more than 43.000 USPTO patents. All American firms in this table have the same ownership structure: they are all conglomerates and are publicly traded. Panel B focuses on British firms, which resemble the American conglomerate structure.[22] Panel C examines the leading innovating firms in France. More than half of these companies are business group affiliates, and seven with minority share-ownership. Only 40% of these firms are publicly traded. As for Germany (panel D), 20% of German firms are partly-owned business-group affiliates. Lastly, 40% of Italian firms are partly-owned business group affiliates (panel E), and only one

[22] Ownership structure in Great Britain differs somewhat from that in the U.S. While the parent company of a British organization is usually publicly traded, all innovative affiliates in our sample are private companies. A good example that illustrates this rather unique structure is GlaxoSmithKline. This pharmaceutical giant has three of its affiliates appearing in the top 20 most innovative firms (Beecham, Glaxo Group, and SmithKline Beecham). Each firm is wholly owned by GlaxoSmithKline holding-company. While the holding company is publicly traded, none of the innovative affiliates are. Glaxo has two headquarters - GlaxoWellcome, and SmithKline Beecham, and a holding company that wholly-owns the whole organization. We classify Glaxo as a conglomerate although it has two headquarters, and a holding company at the apex.

Italian firm is publicly-traded.[23]

Insert Tables 1-3 here

Why do we observe a high concentration of business-groups in Europe, but not in the U.S.? Based on the history of business-groups in the United States, a leading explanation in our view is the tax treatment of intercompany dividends. These have been taxable in the U.S. since the great depression, but are generally not taxable in continental European countries. Under the U.S. tax system, dividend income transferred from a subsidiary to the parent company is subject to a 7.5% tax. A similar tax does not exist in Europe. The U.S. tax reform of the 1930's was a response to the corporate scandals of the late 1920s, and the Roosevelt administration's belief that the proliferation of affiliate firms in business-groups had made these groups very opaque to outsiders, thus creating major governance, tax avoidance, market power, and political influence problems.

In addition to introducing the inter-company dividend tax, the U.S. congress also abolished consolidated tax filings for business-groups, eliminated capital gains taxes on liquidated controlled subsidiaries, and banned large pyramidal groups for controlling public utility companies (the Public Utilites Holdings Company Act or PUHCA of 1935). These policies impose a high penalty on organizing innovation in business-groups in the U.S. Thus, one would expect to observe more business-groups, on average, in Europe, especially in industries where group governance benefits are substantial.

5.2. Comparison across industries

A central theme of this paper is the relationship between organizational form, governance and innovation, and how different organizational forms are best suited to different forms of R&D

[23] In table 3 we do not control for firm age, which means that older firms are more likely to appear on the list of innovative firms than younger ones. We examine the robustness of our findings by looking only at recent patenting activity. Our list of most innovating firms does not appear to be very sensitive to firm age. For example, the largest patentees in the USPTO between 2002 and 2006 are IBM (16.270 patents), Micron Technology (8.383 patents), Intel (7.729 patents), Siemens (7.023 patents), and Robert Bosch (5.870 patents).

activities across industries. Our model, thus, predicts an above average presence of partly-owned affiliates in innovating industries with a stronger need for innovator intellectual property rights protection, and an above-average presence of conglomerates in innovating industries with a faster and more incremental R&D cycle. Thus, in the pharmaceutical industry, where long years of research and development are required, and where the outcome of research is highly uncertain, the hold-up risk is greater. In addition, once a new drug has been discovered and approved, its commercialization is relatively straightforward, so that the innovating team is less dependent on the parent company for marketing and distribution. We thus expect to see a greater presence of partly-owned affiliates in this industry. In contrast, in other industries such as telecommunication, the R&D cycle is much shorter and the outcome is also more predictable. Moreover, any one invention or patent is likely to be harder to commercialize on its own, if it is embedded in other proprietary technologies, which are not owned by the research team. Stronger intellectual property rights protection is then less valuable if the holders of the patent may be held-up anyway by the owners of the essential complementary technology. We therefore expect to see more integrated conglomerate organizational forms in this industry.

Panel A examines industries with a more fundamental and longer innovation cycle, and where patents presumably provide stronger intellectual property protection. We focus on the following industries: pharmaceuticals, biotechnology, chemicals, and automobiles (including mechanical engineering). The general pattern of results is consistent with our analysis. In continental Europe, about 30% of (citations-weighted) patents belong to partly-owned affiliates in pharmaceuticals, 21% in biotechnology, 13% in Chemicals[24], and 18% in automobiles. However, for British and American firms, partly-owned affiliates are very rare, with less than 1% of patents falling in this category for each of the four industries.[25]

We next examine industries with a short innovation life-cycle, and where innovations are

[24] Excluding BASF, 22% of the chemical patents in continental Europe belong to partly-owned affiliates.

[25] There is, however, a striking difference in the ownership structure of British and American firms. For example, in pharmaceuticals, more than 50% of American patents are held by corporate headquarters, as compared to less than 20% of British patents, where the majority of patents (80%) are held by wholly-owned affiliates.

closely inter-related. Commercialization of innovation in these industries therefore often takes the form of a portfolio of interrelated inventions (*patent pools*) that are jointly leveraged to maximize bargaining power in patent litigation disputes and licensing agreements (see Hall and Ziedonis, 2001; Galasso and Schankerman, 2008). Panel B of table 4 examines the following industries: telecommunications, information technology, electronics, and semiconductors. The general pattern of results is again consistent with our analysis. In particular, partly-owned affiliates are extremely rare for all firms: in continental Europe, only 3% of patents belong to partly-owned affiliates in telecommunications, 4% in information technology, 5% in electronics, and 7% in semiconductors[26]. For American and British firms, partly-owned affiliates continue to remain very rare, with less than 1% of patents falling in this category.

These findings are striking, as they indicate that there is a substantial variation in the organizational form of inventive activity in continental Europe across industries, while the variation is much smaller in the U.S. and Great Britain. As expected, industries with more fundamental innovation and stronger intellectual property protection experience a high concentration of patents in partly-owned affiliates. In contrast, industries where the innovation cycle is short and where there are many incremental highly complementary innovations seem to strongly favor centralized organizations in the form of corporate headquarters and wholly-owned affiliates.

Insert Table 4 here

5.3. Econometric analysis

In this section we test the robustness of our findings by controlling for firm and patent characteristics. One concern with our previous analysis is that differences in firm size or age may drive the observed distribution of patents across countries and industries. Such bias can occur, for example, if smaller firms are more likely to be partly-owned affiliates and if countries like France or Italy have a higher fraction of small firms than the U.S. or Great Britain. Similarly,

[26] Excluding Thales Group which is partly-owned by the French state, the percentage of patents that belong to partly-owned affiliates in continental Europe drops from 7% to 1%.

the same pattern would emerge if partly-owned affiliates tend to be younger than corporate headquarters, and if for some reason France and Italy have a higher share of young firms than the U.S. and Great Britain. We test these concerns by estimating a patent-level model of the probability that patent i belongs to a partly-owned affiliate, as a function of patent characteristics (such as quality as measured by citations received, and grant year), the firm that owns it (j), technology area (k), and ultimate owner country (c). Our baseline specification is:

$$\Pr(\mathit{Affiliate}_i) = \Phi(x_j'\beta_1 + \varphi_c + \eta_k + \tau_t) \tag{5.1}$$

$Affiliate_i$ receives the value of one if it belongs to a partly-owned affiliated firm that have minority shareholders, and zero for firms of other organizational forms. x_j is a vector of characteristics of the firm that holds patent i (such as firm age, and sales), φ_c is a set of country dummies (or dummies that group firms to US, British, and continental European), η_k is a set of technology field dummies, and τ_t is a set of patent grant year dummies. Country assignment is based on the nationality of the ultimate owner. To ensure even coverage across countries when controlling for firm characteristics, we exclude firms that, on average, have less than 20 employees and generate less than $1 million in annual sales (we also drop firms where employment and sales information is never available). Our main interest is in the country and technology field dummies. In later specifications we also estimate the interaction terms between country and technology area dummies to examine how differences in organizational forms between Europe and the U.S. vary across technology areas. We estimate equation 5.1 using a linear probability model. Standard errors are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms.

Table 5 summarizes the estimation results. Column 1 includes dummies for continental Europe and British firms (the U.S. is the baseline category). Consistent with our previous findings, the coefficient on the dummy for continental Europe is positive and is highly significant. On average, the probability that a continental European firm is a partly-owned affiliate is higher by 13.2% than an American firm. The coefficient on the dummy for British firms is close to zero and not significant, indicating that American and British firms have practically the same probability of being partly-owned affiliates (the predicted probability of partly-owned affiliates in the whole sample, evaluated at the mean, is less than one percent). In column 2 we control for firm sales, age, and a dummy for whether it is public. The coefficient on the dummy for continental Europe slightly drops, but remains highly significant (0.126 and a standard error of 0.046). Column 3 breaks down the dummy for continental Europe by including separate dummies for German, French, and Italian firms. We group the remaining European countries under *Other Europeans*. The same pattern of results continues to hold where France and Italy firms are most likely to be partly-owned affiliates (coefficients of 0.240 and 0.337, with standard errors of 0.097 and 0.104, respectively). We reject the null hypothesis the British firms have the same partly-owned affiliation probability as German, French, and Italian firms. The respective χ^2-*statistics* (*p-value*) for coefficient equality are 9.87 ($p\text{-}value<0.002$), 11.59 ($p\text{-}value<0.0001$), and 20.05 ($p\text{-}value<0.0001$), for Germany, France, and Italy, respectively. Columns 4-7 examine the robustness of the results to patents quality, as measured by the number of citations they receive, and firm age at the year the patent was granted. The results continue to hold.

Columns 8-10 explore how the effect of continental Europe dummy on the probability of partly-owned affiliation varies across technology areas. We now interact the continental Europe dummy with technology area dummies. Details on how we classify the main technology areas are available in the appendix. We expect positive and high coefficients on the interactions with pharmaceuticals, biotechnology, and chemicals, and substantially lower ones for electronics, information technology, and telecommunications. The results confirm our expectations and are aligned with our previous descriptive findings. The coefficient on the interaction between continental Europe and pharmaceuticals dummies is 0.539 (a standard error of 0.212). This coefficient indicates that for a pharmaceuticals patents, the probability it belongs to a partly-owned affiliate is higher by 53.9% if the patent is owned by a European firm than if it is owned by an American firm. A similar pattern (though with lower coefficients) is also evident for biotechnology and chemicals. However, for patents in Electronics, Information Technology, and Telecommunications, the respective interaction coefficients are effectively zero, indicating that there is no substantial difference in the probability of partly-owned affiliation between the continental European and American and British firms (e.g., the coefficient between continental Europe and telecommunications dummies is -0.006 with a standard error of 0.002). Columns 8-9 find the same pattern of results for patents that either receive few or many citations.

These are perhaps the most striking findings of this study. They suggest, in particular, that previous cross-country studies may have put too much weight on differences in legal and corporate law protections to explain the variation in the prevalence of business-groups across Europe and the U.S. Our results suggest that the observed average cross-country differences in the prevalence of business groups may be driven as much by cross-country differences in industry composition, at least for innovating firms. Importantly, our findings that organizational form systematically varies with industry characteristics is also consistent with a *Coasian view* of how firms organize themselves: namely that R&D intensive firms tend to choose the corporate form most conducive to innovation. This is especially true in Europe, where there are fewer regulatory hurdles to the formation of business groups and hybrid corporate forms. It is not the case in the U.S., where tax and regulatory hurdles essentially eliminate any gains from forming business groups, and where a highly visible VC and private equity sector provides an alternative to business-group financing of R&D.

Insert Table 5 here

6. Conclusion

This paper examines the relation between organization form and innovation for a cross-section of private and publicly traded innovating firms in the U.S. and 15 European countries. Several new findings emerge from our analysis. While most innovating firms in the U.S. are publicly traded conglomerates, a substantial fraction of innovation is concentrated in private firms and in business groups in continental European countries. There is a substantial variation in organization form across industries. Partly-owned affiliates tend to be concentrated in industries where innovation takes time, is highly uncertain, and where the intellectual protection of the innovator may be of paramount importance. On the other hand, conglomerates are more prevalent in industries with rapid, incremental, innovation where the ability of corporate headquarters to promptly identify the relevant innovation and to quickly redeploy assets may give it an edge over business groups. This is especially true in Europe, where there are fewer regulatory hurdles to the formation of business groups and hybrid corporate forms. It is not the case in the U.S., where tax and regulatory hurdles essentially eliminate any gains from forming business groups, and where a highly visible VC and private equity sector provides an alternative to business-group financing of R&D.

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A. Appendix

A.1. Industry patent classification

Table 4 summarizes the distribution of patents across industries. The classification of patents to these industries is based on the patent International Patent Classification, as following. Biotechnology: A01H C02F3/34 C07G11 C07G13 C07G15 C07K4 C07K14 C07K16 C07K17 C07K 19/00 C12M C12N C12P C12Q C12S G01N 27/327 G01N 33/53 G01N 33/54 G01N 33/55 G01N 33/57 G01N 33/68 G01N 33/74 G01N 33/76 G01N 33/78 G01N 33/88 G01N 33/92, Pharmaceuticals: A61K A61P, Chemicals: C0 C1 B01 D01F A62D (excluding Biotechnology), Agriculture: A01 (excluding A01H), Food: A21, A22, A23, Apparel: A41, A42, A43, Medical equipment: A61B A61C A61D A61F A61G A61HA61J A61L A61M A61N A61Q, Printing B4, Automobiles B60, Transportation: B6 (excluding B60), Energy: C10G C10L, Metallurgy: C21 C22 C23 C25 C30, Construction: E0, Machinery: F01 F02 F03 F04, Engineering (part of automobiles): F15 F16 F17, Measuring: G01 (excluding Biotechnology) G02 G03F G03H G08 G09 G10 G12B G15 G21 F24J, Information Technology: G05B G05D G06F (excluding G06F17,G06F15,G06F11) G06J G06K G06N G06T G11B, Electronics: H01L H03 G11C G06C G06D G06E G06F11 G06F15 G06F17 G06G H01(excluding H01L) H02 H04 (excluding H04N H04L H04M) H05 B03C, Telecommunications: H04L H04M H04N.

A.2. Constructing ownership structure

This appendix builds on Belenzon and Berkovitz (2010) and is included here for completeness. This section details the construction and output of our ownership algorithm. A description of the algorithm is available in Belenzon and Berkovitz, 2010, and is provided here for completeness. The purpose of the algorithm is to determine the structure of European business-groups based on the Amadeus ownership database. The algorithm consists of two parts: a control-chain generator that constructs the ownership and control links between different European firms, and a name matching procedure that groups together firms controlled by the same ultimate owner. Our source of information is the ownership sections of the 2008 versions of Amadeus (for the European subsidiaries) and Icarus (for the American subsidiaries).

A.2.1. The Control chain generator

The Amadeus ownership database includes detailed information on the percentage of ownership between European corporate shareholders and their European subsidiaries. The data span virtually all European countries (including Eastern Europe). Icarus provides similar information for the United States. We develop an ownership algorithm that constructs the internal structure of business-groups based on these inter-company ownership links. The main benefits of the algorithm are: (i) it constructs the ownership chains without relying on the (often missing) information on whether an ownership link is direct or indirect,[27] (ii) it completes missing ownership links by transitivity, (iii) it identifies cross-holdings, and (iv) it handles complex ownership structures. These features allow us to develop robust measures of business-group characteristics (such as group size).

[27] Indirect ownership links are very common in our data. Suppose, for example, that firm A owns 60% of the shares of B and that B owns 60% of the shares of C. In this case, firm A has a *direct ownership* of 60% in B and an *indirect ownership* of 36% in C.

We include all ownership links from the Amadeus ownership database that represent a control relation. For this, we make the following assumptions: for private subsidiaries, a shareholder exerts control if its direct percentage of ownership is larger than 50. For public firms, the percentage of direct ownership has to be larger than 20 to represent a control relation (since ownership is typically less concentrated in public firms than in private firms).[28]

There are about 1 million direct ownership links that satisfy our control assumptions, where 291.974 shareholders control 789.557 subsidiaries. The average percentage of direct ownership is 91 with a median of 100 (59 percent of the ownership links represent a wholly-owned relation). There are 1.369 public subsidiaries. For these public subsidiaries, the average percentage of direct ownership is 53 with a median of 48. The input file of direct ownership links generates 718.092 ownership chains. 69 percent of the chains include only two firms (13 percent of the chains include more than 3 firms and 3 percent of the chains include more than 5 firms). 63 percent of the chains are wholly-owned (for all levels in the chain). For chains where the apex in an American or British firms, 83 percent are wholly-owned, for German apex firms, 60 percent of the chains are wholly-owned, where for French apex firms, only 25 percent are wholly-owned.

A.2.2. Description of the algorithm

The algorithm follows three steps: (i) completes missing ownership links, (ii) generates lists of all subsidiaries and parents for each company, and (iii) constructs the ownership chains bottom-up.[29] To illustrate our methodology, it would be useful to consider the following example. Suppose Figure A.1 correctly describes the ownership structure of a business-group. The ultimate owner (for example, a family) at the apex of the group controls 7 public and private firms. Amadeus provides detailed data on direct ownership links. Thus, our raw data include the links $A \rightarrow D$, $B \rightarrow F$, $C \rightarrow G$, and $D \rightarrow E$. Note that the percentage of ownership for the link $C \rightarrow G$ has to be larger than 20 (because firm G is public), where for the percentage of ownership for all other links has to be larger than 50 (because the other subsidiaries are private). Because there is no information about indirect ownership links, the link $A \rightarrow E$ is missing from the raw data. The first step of the algorithm is to complete missing links. As we observe the ownership relations $A \rightarrow D$ and $D \rightarrow E$, our algorithm infers the ownership relation $A \rightarrow E$. Note that at this stage of the algorithm we still do not know whether the ownership relation is direct or indirect (and if it is indirect, how many layers separate firm E from firm A). The second step of the algorithm is to construct two lists for each firm: shareholders and subsidiaries. This step saves valuable running time, which is especially important when dealing with large scale ownership data. The following table is generated:

[28] Similar assumption was made by La Porta et al. (1999) and Faccio and Lang (2002).

[29] Unlike business groups in East Asia (such as the Japanese keiretsu), most European business groups are organized in pyramids (Figure A.1). This means that interlocking shareholdings are not common and, therefore, ownership chains can be constructed bottom-up.

Firm	Shareholder	Subsidiary
A	-	D, E
B	-	F
C	-	G
D	A	E
E	A, D	-
F	B	-
G	C	-

Note that from step 1, we already know that firm A is a shareholder of firm E. Also, because we assume the ultimate owner is a family, firms A, B, and C have no corporate (European) shareholder. The third and final step of the algorithm is to construct the structure of the group based on the above ownership relations. Because of the missing links problem, our algorithm does not assume that an ownership relation is direct; the only input the algorithm receives is the existence of the ownership relation. We start with a firm that has no subsidiaries from the list generated in step 2. We illustrate the procedure for firm E, which is the most interesting in this example. Firm E is placed at the bottom of the ownership chain. Next, we move to the shareholder list of firm E. It includes firms A and D. Starting arbitrary with A, place A above E. Proceeding to firm D, there are three possibilities for its location: (i) D is above E and above A; (ii) D is above E, but below A; (iii) D is above E, but not below neither above A (different ownership chain). For (i) to be the right structure, D has to appear in the shareholder list of firm A. From step 2, we rule this out. For (ii) to be the right structure, D has to appear on the subsidiary list of firm A. From step 2, this holds. Finally, for (iii) to be the right structure, A cannot appear on either the shareholder or subsidiary lists of firm D. From step 2, this is ruled out. At the end of this procedure, we have determined for each ownership chain the highest shareholder firm - we call this firm the leading shareholder.

Our algorithm fails in the case of cross-holdings. A cross-holding is an ownership structure where a shareholder is also a subsidiary of its own subsidiary. For example, suppose we also observe the ownership link $E \rightarrow A$. Our ordering procedure will not work because there is no starting point: no firm is placed at the bottom of the business-group and, therefore, the leading shareholder cannot be determined.[30] Yet, we observe only few cases of cross-holdings in the data (0.5 percent of the ownership links are associated with at least one cross-holding).

[30] A less 'severe' case of cross-holding is where we observe $E \rightarrow D$. In this case, our algorithm constructs two ownership chains: $A \rightarrow D \rightarrow E$ and $A \rightarrow D \rightarrow E$, where both correctly characterize the ownership structure. The leading shareholder is firm A in both cases, which allows us to correctly group firms into business groups.

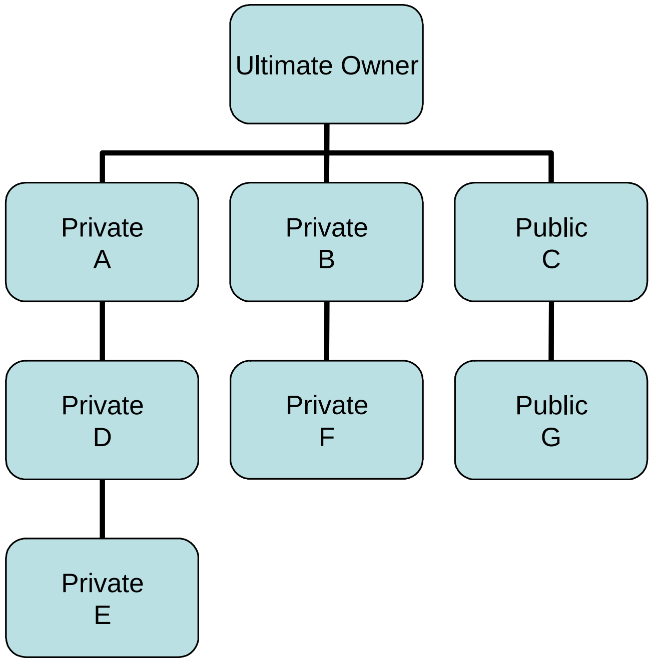


Figure A.1: Example of a business-group

A.2.3. Ultimate owner name matching

The next part of our algorithm groups firms across ownership chains based on the name of the ultimate owners. The name matching process deals with two main issues. First, ultimate owner names are not standardized, i.e., the same name can be spelled differently across subsidiaries. Second, common names, especially for family members, may lead to 'over-grouping'. We deal with theses issues as following. First, we develop a name standardization procedure that harmonizes the different string patterns in our data. Second, to ensure families are indeed wealthy, we search for publicly available information, such as Forbes and The Economist, on the largest 500 wealthiest families in our sample (for example, De Rotchild family, Nasi-Agnelli family). For the other individual ultimate owners in our sample, we compute the frequency of the appearance of the name in the ultimate owner population. In case this frequency is higher than the median frequency, we assume the common name problem and do not include that ultimate owner in our sample. Our control assumptions may lead to cases where we miss-classify firms to groups. For example, suppose an ultimate owner controls 33 percent of firm C, and firms A and B control each 33 percent of firm C. Assuming firm C is private, our algorithm will not assign firm C to a group. The ultimate owner fully controls firm C (via its control of firms A and B), thus firm C should be part of the group. To deal with this situation we take the following step. For firms that were not assigned to groups we extract a list of their immediate shareholders (corporate and individuals). For each shareholder we already know whether it belongs to a group and its ultimate owner (as indicated by the ownership algorithm). Then, we examine whether an ultimate owner controls more than 50 percent of the stocks for private firms and more than 20 percent of the stocks for public firms. In case the aggregated holding of the ultimate owner meets these threshold, we assign the affiliate to the group.

A.3. Matching patent data

A.3.1. European Patent Office (EPO)

This appendix builds on Belenzon and Berkovitz (2010) and is included here for completeness. Our main information source on patents is the 2007 publication of the PATSTAT database, which is the standard source for European patent data. This database contains all bibliographic data (including citations) on all European patent applications and granted patents, from the beginning of the EPO system in 1979 to the end of 2007. We match the name of each EPO applicant listed on the patent document to the full name of a firm listed in Amadeus (about 8 million names). Since we are interested only in matching patent applicants to firms, we exclude applicant names that fall into the following categories: government agencies, universities, and individuals. We identify government agencies and universities by searching for a set of identifying strings in their name. We identify individuals as patents where the assignee and the inventor name strings are identical.

The matching procedure follows two main steps. (i) Standardizing names of patent applicants. This involves replacing commonly used strings which symbolize the same thing, for example "Ltd." and "Limited" in the UK. We remove spaces between characters and transform all letters to capital letters. As an example, the name "British Nuclear Fuels Public Limited Company" becomes "BRITISHNUCLEARFUELSPLC". (ii) Name matching: match the standard names of the patent applicants with Amadeus firms. If there is no match, then try to match to the old firm name available in Amadeus. We need to confront a number of issues. First, in any given year, the Amadeus database excludes the names of firms that have not filed financial reports for four consecutive years (e.g. M&A, default). We deal with this issue in several ways. First, we use information from historical versions of the Amadeus database (1995-2006) on names and name changes. Second, even though Amadeus contains a unique firm identifier (BVD ID number), there are cases in which firms with identical names have different BVD numbers. In these cases, we use other variables for identification, for example: address (ZIP code), Date of incorporation (whether consistent with the patent application date), and more. Finally, we manually match most of the remaining corporate patents to the list of Amadeus firms.

Some groups assign many of their patents to a single subsidiary. This subsidiary typically does not innovate and its main purpose is to manage the intellectual property assets of the group. We identify such firms using their SIC classification, or in some instances, their name. We use information on the location of the patent inventors to match the centrally-assigned patents to innovative affiliates. The secondary assignment of these patents is based on a match between the address of the patent inventor and the group affiliates. In case the address of the inventor matches multiple group affiliates we make the following assumption: if only one of the affiliates innovates (as indicated by the number of patents this affiliate already has), assign the patent to this innovative affiliate. If more than one of the matched affiliates innovates, keep the original central assignment of the patent. The secondary matching procedure increases the number of innovative affiliates by about 250 firms.

A.3.2. United States Patents and Trademarks Office (USPTO)

The procedure described above matches European firms to patents registered with the EPO. Yet, some European firms register patents only with the USPTO, without applying to the

EPO. In order to identify the European firms that only apply to the USPTO, we match the complete set of Amadeus firms to the name of the patent applicants from the USPTO. The most updated patent database for the USPTO is the 2002 version of the NBER patents and citations data archive. Because this database covers patent information only up to 2002 and our accounting data go up to 2007, we updated the patent data file by extracting all information about patents granted between 2002 and 2007 directly from the USPTO website.[31] Having updated the USPTO patent database, we follow the matching procedure described above to create the matched USPTO patent data for the Amadeus firms.

A.4. Matching scientific publications

This appendix builds on Belenzon and Patacconi (2009) and is included here for completeness. The largest database on scientific publications is the ISI Web of Knowledge (WoK) by Thomson. This includes millions of records on publications in academic journals. The data is divided to three main categories based on the publication type: hard sciences, social sciences, and arts and humanities. Because we are interested in capturing investment in scientific research, we focus only on the hard sciences section of WoK. This section includes publication records over the period 1970-2007. The address field on each record indicates the affiliation of the authors of the publication. This affiliation is typically either a research institution or a firm. We use the name appearing in this field and match it to the complete list of Amadeus firms. We follow the same matching procedure as described above for the EPO and USPTO patent matching. Articles may have more than one author (the median number of authors per article is 2). In this case, the address field would include multiple affiliations. We assign a scientific publication to a specific firm if the name of this firm appears at least once in the address field of the article. This procedure means that a single article can be assigned to more than one firm, but a firm cannot be assigned more than once to the same article. For each article, we also extract information on the number of times it was cited, the journal in which it was published, and the year of publication. Information about the importance of journals is taken from the Journal Citations Report index (JCR). Finally, European research institutions can be incorporated, thus, they appear in Amadeus as potential firms to be matched. To screen out such firms, we follow two steps. First, as for patent matching, we drop Amadeus names that include strings that are associated with research institutions (such as, UNIVERSITY, RESEARCH, INSTITUTION, etc.). Second, we manually examine the websites of firms that have a large number of publications but appear as small firms in terms of their sales and number of patents. For these firms, we check whether their primary activity is research. In case the primary activity is research, we exclude them from our matched sample.

[31] http://patft.uspto.gov/netahtml/PTO/srchnum.htm

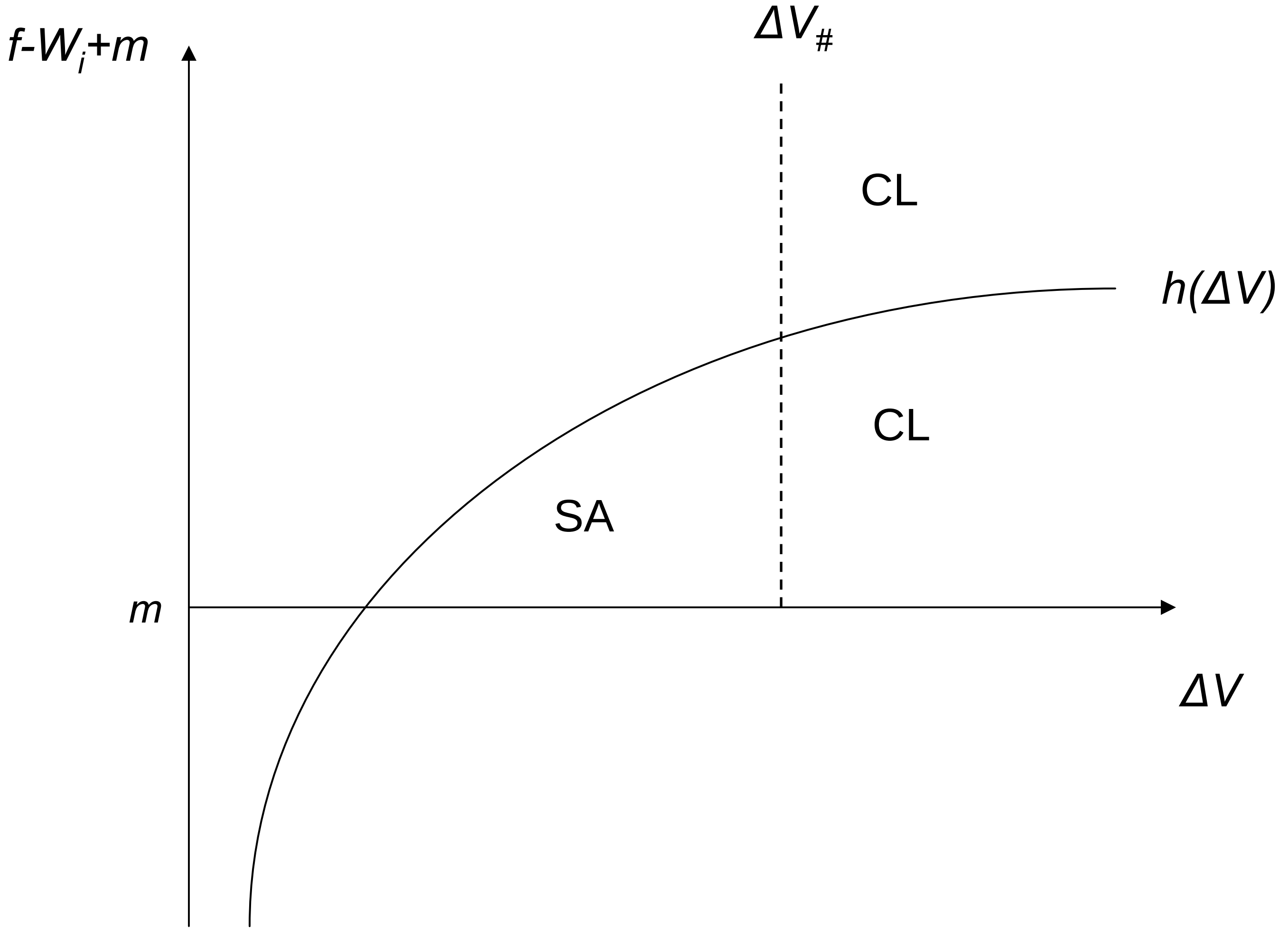


Figure 1

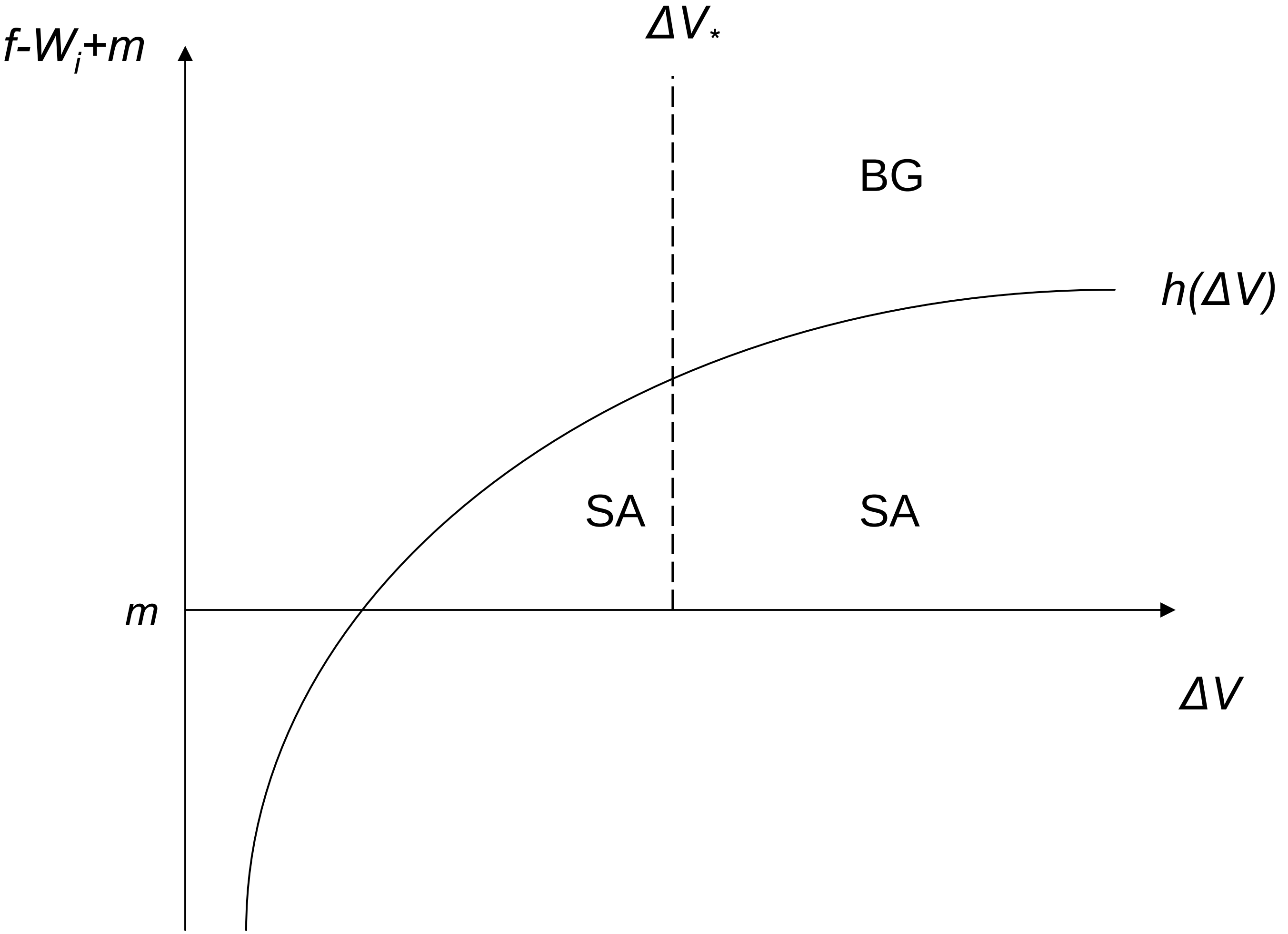


Figure 2

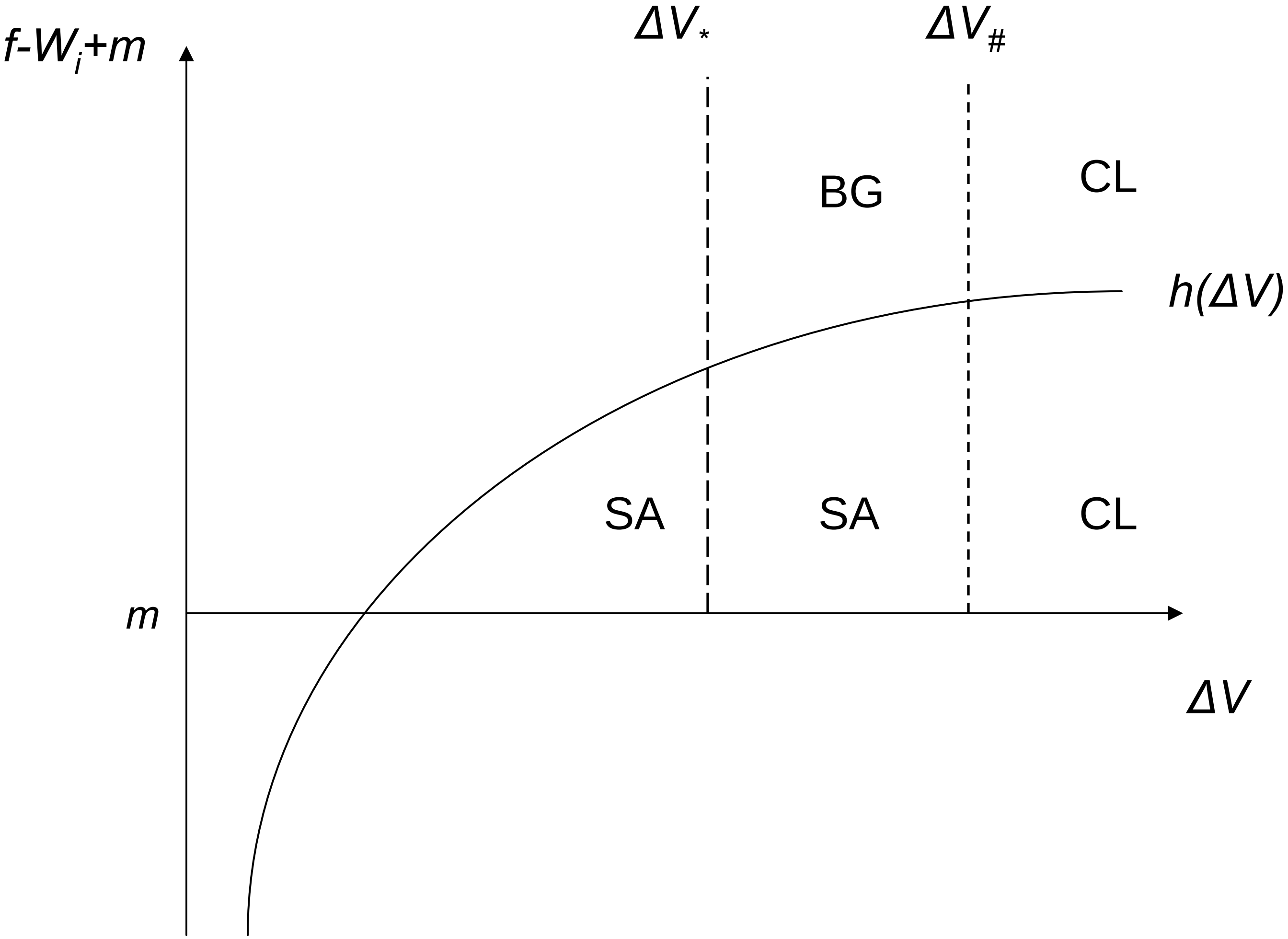


Figure 3

TABLE 1:

INNOVATION AND OWNERSHIP STRUCTURE ACROSS COUNTRIES

Panel A. Number of firms

Ultimate Owner Country	*Stand Alone*	*Corporate Headquarters*	*Affiliates*			*Total*
			All affiliates	Wholly-owned	Partly-owned	
Austria	401	72	312	231	81	785
	(51%)	(9%)	(40%)	(29%)	(10%)	
Belgium	299	72	348	229	119	719
	(42%)	(10%)	(48%)	(32%)	(17%)	
Denmark	496	48	265	207	58	809
	(61%)	(6%)	(33%)	(26%)	(7%)	
Finland	564	95	254	193	61	913
	(62%)	(10%)	(28%)	(21%)	(7%)	
France	717	203	1,445	814	631	2,365
	(30%)	(9%)	(61%)	(34%)	(27%)	
Germany	4,087	803	2,152	1,583	569	7,042
	(58%)	(11%)	(31%)	(22%)	(8%)	
Great Britain	2,247	373	2,260	2,146	114	4,880
	(46%)	(8%)	(46%)	(44%)	(2%)	
Greece	16	8	9	6	3	33
	(48%)	(24%)	(27%)	(18%)	(9%)	
Italy	2,280	303	535	283	252	3,118
	(73%)	(10%)	(17%)	(9%)	(8%)	
Netherlands	75	44	499	432	67	618
	(12%)	(7%)	(81%)	(70%)	(11%)	
Norway	243	62	233	132	101	538
	(45%)	(12%)	(43%)	(25%)	(19%)	
Republic of Ireland	25	5	60	49	11	90
	(28%)	(6%)	(67%)	(54%)	(12%)	
Spain	408	80	223	125	98	711
	(57%)	(11%)	(31%)	(18%)	(14%)	
Sweden	295	115	654	535	119	1,064
	(28%)	(11%)	(61%)	(50%)	(11%)	
Switzerland	684	145	623	552	71	1,452
	(47%)	(10%)	(43%)	(38%)	(5%)	
Total Europe	*12,837*	*2,428*	*9,872*	*7,517*	*2,355*	*25,137*
	(51%)	*(10%)*	(39%)	(30%)	*(9%)*	
United States	27,495	4,842	6,503	6,298	205	38,840
	(71%)	(12%)	(17%)	(16%)	(1%)	
Total	40,332	7,270	16,375	13,815	2,560	63,977
	(63%)	(11%)	(26%)	(22%)	(4%)	

Note: This table examines the distribution of the number of innovating firms by organizational form and by country. We include all firms that have at least one patent from the USPTO (1975-2007), at least one patent from the EPO (1978-2007), or at least one scientific publication (1970-2007). A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 1: *(Cont'd)*

INNOVATION AND OWNERSHIP STRUCTURE ACROSS COUNTRIES

Panel B. Patents from the USPTO (weighted by citations)

Ultimate Owner Country	*Stand Alone*	*Corporate headquarters*	*Affiliates*			*Total*
			All affiliates	Wholly-owned	Partly-owned	
Austria	100.0	226.6	410.2	324.7	85.5	736.8
	(14%)	(31%)	(56%)	(44%)	(12%)	
Belgium	140.5	178.8	431.6	336.1	95.5	750.9
	(19%)	(24%)	(57%)	(45%)	(13%)	
Denmark	171.1	779.1	545.8	356.7	189.1	1,496.0
	(11%)	(52%)	(36%)	(24%)	(13%)	
Finland	130.5	3,439.6	290.7	196.9	93.8	3,860.8
	(3%)	(89%)	(8%)	(5%)	(2%)	
France	166.4	1,907.9	12,601.4	9,680.1	2,921.3	14,675.7
	(1%)	(13%)	(86%)	(66%)	(20%)	
Germany	4,390.6	23,692.9	12,631.5	9,680.2	2,951.3	40,715.0
	(11%)	(58%)	(31%)	(24%)	(7%)	
Great Britain	2,421.6	4,867.5	8,800.2	8,731.9	68.3	16,089.3
	(15%)	(30%)	(55%)	(54%)	(0%)	
Greece	4.8	0.0	1.1	0.0	1.1	5.9
	(81%)	(0%)	(19%)	(0%)	(19%)	
Italy	1,193.7	190.3	1,006.4	547.9	458.5	2,390.4
	(50%)	(8%)	(42%)	(23%)	(19%)	
Netherlands	22.1	2,372.9	2,348.0	2,089.1	258.9	4,743.0
	(0%)	(50%)	(50%)	(44%)	(5%)	
Norway	72.5	92.4	136.5	119.4	17.1	301.4
	(24%)	(31%)	(45%)	(40%)	(6%)	
Republic of Ireland	3.5	31.8	79.7	75.8	3.9	115.0
	(3%)	(28%)	(69%)	(66%)	(3%)	
Spain	46.3	27.5	284.3	230.6	53.7	358.1
	(13%)	(8%)	(79%)	(64%)	(15%)	
Sweden	79.5	574.5	3,826.9	3,593.1	233.8	4,480.9
	(2%)	(13%)	(85%)	(80%)	(5%)	
Switzerland	549.2	1,058.7	5,679.9	4,147.6	1,532.3	7,287.8
	(8%)	(15%)	(78%)	(57%)	(21%)	
Total Europe	*9,492.3*	*39,440.5*	*49,074.2*	*40,110.1*	*8,964.1*	*98,007.0*
	(10%)	*(40%)*	(50%)	(41%)	*(9%)*	
United States	86,093.5	293,129.4	62,506.4	61,662.9	843.5	441,729.3
	(19%)	(66%)	(14%)	(14%)	(0%)	
Total	95,585.8	332,569.9	111,580.6	101,773.0	9,807.6	539,736.3
	(18%)	(62%)	(21%)	(19%)	(2%)	

Note: This table examines the distribution of USPTO patents by organizational form and by country. Patents are weighted by the number of citations they receive. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 1: *(Cont'd)*

INNOVATION AND OWNERSHIP STRUCTURE ACROSS COUNTRIES

Panel C. Patents from the EPO (weighted by citations)

Ultimate Owner Country	*Stand Alone*	*Corporate headquarters*	*Affiliates*			*Total*
			All affiliates	Wholly-owned	Partly-owned	
Austria	243.0	322.8	781.8	650.5	131.3	1,347.6
	(18%)	(24%)	(58%)	(48%)	(10%)	
Belgium	276.0	289.4	542.5	253.1	289.4	1,107.9
	(25%)	(26%)	(49%)	(23%)	(26%)	
Denmark	92.5	289.9	219.0	172.7	46.3	601.4
	(15%)	(48%)	(36%)	(29%)	(8%)	
Finland	103.2	2,347.4	175.3	153.0	22.3	2,625.9
	(4%)	(89%)	(7%)	(6%)	(1%)	
France	288.9	3,210.7	11,939.1	8,281.3	3,657.8	15,438.7
	(2%)	(21%)	(77%)	(54%)	(24%)	
Germany	4,306.5	22,903.7	8,038.2	4,527.6	3,510.6	35,248.4
	(12%)	(65%)	(23%)	(13%)	(10%)	
Great Britain	1,254.4	2,994.4	8,637.7	8,605.4	32.3	12,886.5
	(10%)	(23%)	(67%)	(67%)	(0%)	
Greece	0.3	0.7	1.5	1.5	0.0	2.5
	(12%)	(28%)	(60%)	(60%)	(0%)	
Italy	1,297.3	490.3	1,552.0	646.1	905.9	3,339.6
	(39%)	(15%)	(46%)	(19%)	(27%)	
Netherlands	58.0	5,607.5	2,498.2	2,450.2	48.0	8,163.7
	(1%)	(69%)	(31%)	(30%)	(1%)	
Norway	19.8	106.7	28.7	24.5	4.2	155.2
	(13%)	(69%)	(18%)	(16%)	(3%)	
Republic of Ireland	2.1	7.9	42.9	40.5	2.4	52.9
	(4%)	(15%)	(81%)	(77%)	(5%)	
Spain	103.3	76.3	245.6	196.4	49.2	425.2
	(24%)	(18%)	(58%)	(46%)	(12%)	
Sweden	77.5	406.6	1,838.3	1,745.2	93.1	2,322.4
	(3%)	(18%)	(79%)	(75%)	(4%)	
Switzerland	754.0	1,489.9	6,722.6	6,610.4	112.2	8,966.5
	(8%)	(17%)	(75%)	(74%)	(1%)	
Total Europe	*8,876.8*	*40,544.2*	*43,263.4*	*34,358.4*	*8,905.0*	*92,684.4*
	(10%)	*(44%)*	(47%)	(37%)	*(10%)*	
United States	1,170.2	14,440.6	7,921.0	7,759.2	161.8	23,531.8
	(5%)	(61%)	(34%)	(33%)	(1%)	
Total	10,047.0	54,984.8	51,184.4	42,117.6	9,066.8	116,216.2
	(9%)	(47%)	(44%)	(36%)	(8%)	

Note: This table examines the distribution of EPO patents by organizational form and by country. Patent are weighted by the number of citations they receive. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 1: *(Cont'd)*

INNOVATION AND OWNERSHIP STRUCTURE ACROSS COUNTRIES

PANEL D. Scientific publications

Ultimate Owner Country	*Stand Alone*	*Corporate headquarters*	*Affiliates*			*Total*
			All affiliates	Wholly-owned	Partly-owned	
Austria	105 (11%)	119 (12%)	735 (77%)	679 (71%)	56 (6%)	959
Belgium	275 (31%)	137 (15%)	480 (54%)	293 (33%)	187 (21%)	892
Denmark	12 (1%)	1,146 (73%)	410 (26%)	346 (22%)	64 (4%)	1,568
Finland	239 (33%)	231 (32%)	246 (34%)	215 (30%)	31 (4%)	716
France	358 (4%)	542 (6%)	8,147 (90%)	7,126 (79%)	1,021 (11%)	9,047
Germany	3,386 (16%)	8,519 (40%)	9,185 (44%)	5,543 (26%)	3,642 (17%)	21,090
Great Britain	2,245 (28%)	983 (12%)	4,862 (60%)	4,776 (59%)	86 (1%)	8,090
Greece	14 (56%)	6 (24%)	5 (20%)	3 (12%)	2 (8%)	25
Italy	531 (41%)	179 (14%)	573 (45%)	419 (33%)	154 (12%)	1,283
Netherlands	100 (4%)	151 (7%)	2,015 (89%)	1,865 (82%)	150 (7%)	2,266
Norway	193 (49%)	29 (7%)	175 (44%)	110 (28%)	65 (16%)	397
Republic of Ireland	14 (16%)	7 (8%)	67 (76%)	62 (70%)	5 (6%)	88
Spain	149 (30%)	95 (19%)	252 (51%)	126 (25%)	126 (25%)	496
Sweden	167 (15%)	379 (34%)	564 (51%)	410 (37%)	154 (14%)	1,110
Switzerland	905 (6%)	583 (4%)	13,080 (90%)	11,517 (79%)	1,563 (11%)	14,568
Total Europe	*8,693* *(14%)*	*13,106* *(21%)*	*40,796* (65%)	*33,490* (54%)	*7,306* *(12%)*	*62,595*
United States	33,716 (24%)	82,616 (59%)	23,764 (17%)	23,128 (17%)	636 (0%)	140,096
Total	42,409 (21%)	95,722 (47%)	64,560 (32%)	56,618 (28%)	7,942 (4%)	202,691

Note: This table examines the distribution of firm scientific publications by organizational form and by country. We match European and American firms to the ISI Web of Knowledge, and assign a publication to a firm if at least one of the publication authors is affiliated with the firm. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 2:

PRIVATE AND PUBLIC INNOVATING FIRMS

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
	# of firms			USPTO Patents			Sales ($M), All firms		
Ultimate Owner Country	Private	Public	Total	Private	Public	Total	Private	Public	Total
Austria	759	26	785	526	211	737	575,754	4,156	579,911
	(97%)	(3%)		(71%)	(29%)		(99%)	(1%)	
Belgium	688	31	719	502	249	751	742,224	128,553	870,776
	(96%)	(4%)		(67%)	(33%)		(85%)	(15%)	
Denmark	786	23	809	867	629	1,496	223,507	10,387	233,893
	(97%)	(3%)		(58%)	(42%)		(96%)	(4%)	
Finland	865	48	913	447	3,414	3,861	393,243	200,470	593,713
	(95%)	(5%)		(12%)	(88%)		(66%)	(34%)	
France	2,235	130	2,365	17,914	2,176	20,091	4,784,883	1,768,054	6,552,937
	(95%)	(5%)		(89%)	(11%)		(73%)	(27%)	
Germany	6,886	156	7,042	24,539	16,176	40,715	7,757,845	1,588,073	9,345,918
	(98%)	(2%)		(60%)	(40%)		(83%)	(17%)	
Great Britain	4,733	147	4,880	11,416	4,673	16,089	4,880,578	2,042,093	6,922,671
	(97%)	(3%)		(71%)	(29%)		(71%)	(29%)	
Greece	26	7	33	5	1	6	112,619	56,834	169,454
	(79%)	(21%)		(81%)	(19%)		(66%)	(34%)	
Italy	3,076	42	3,118	2,332	59	2,390	2,211,228	19,502	2,230,730
	(99%)	(1%)		(98%)	(2%)		(99%)	(1%)	
Netherlands	592	26	618	2,352	2,391	4,743	1,891,771	436,698	2,328,469
	(96%)	(4%)		(50%)	(50%)		(81%)	(19%)	
Norway	515	23	538	26	48	73	516,874	167,637	684,511
	(96%)	(4%)		(35%)	(65%)		(76%)	(24%)	
Republic of Ireland	88	2	90	84	31	115	480,214	51,707	531,921
	(98%)	(2%)		(73%)	(27%)		(90%)	(10%)	
Spain	682	29	711	352	6	358	2,156,651	354,403	2,511,055
	(96%)	(4%)		(98%)	(2%)		(86%)	(14%)	
Sweden	1,012	53	1,065	3,959	522	4,481	946,218	252,329	1,198,547
	(95%)	(5%)		(88%)	(12%)		(79%)	(21%)	
Switzerland	1,407	44	1,451	5,051	2,237	7,288	1,066,802	434,314	1,501,116
	(97%)	(3%)		(69%)	(31%)		(71%)	(29%)	
Total Europe	*24,350*	*787*	*25,137*	*70,371*	*32,823*	*103,194*	*28,740,411*	*7,515,210*	*36,255,621*
	(97%)	*(3%)*		*(68%)*	*(32%)*		*(79%)*	*(21%)*	
United States	37,381	1,459	38,840	165,005	276,653	441,658	21,549,584	11,402,980	32,952,564
	(96%)	(4%)		(37%)	(63%)		(65%)	(35%)	
Total	61,731	2,246	63,977	235,376	309,476	544,852	50,289,995	18,918,190	69,208,185
	(96%)	(4%)		(43%)	(57%)		(73%)	(27%)	

Note: This table examines the distribution of patents for private and publicly listed firms across countries. Columns 1-3 report the distribution for the number of innovating firms, where a firm is classified as innovative if it has at least one patent from the USPTO or the EPO, or if it has at least one scientific publication. Columns 4-6 examine the distribution for citations-weighted number of USPTO patents. Column 7-9 examine the distribution of sales for all firms in the economy, including firms that never patent.

TABLE 3:

PANEL A. TOP 20 INNOVATING AMERICAN FIRMS

	Company name	Firm public	Group public	Total Group Patents USPTO	Patents USPTO	Patents EPO	Publications	Ultimate Owner	Organizational form
(1)	IBM	Yes	Yes	43,241	43,125	14,319	0	IBM	Corp. headquarters
(2)	General Electric	Yes	Yes	22,348	21,830	9,641	93	General Electric	Corp. headquarters
(3)	Eastman Kodak	Yes	Yes	17,441	17,157	9,676	3,361	Eastman Kodak	Corp. headquarters
(4)	Motorola	Yes	Yes	17,639	16,380	4,839	2,409	Motorola	Corp. headquarters
(5)	Micron Technology	Yes	Yes	13,986	13,986	561	119	Micron Technology	Corp. headquarters
(6)	Intel	Yes	Yes	12,936	12,934	2,103	2,285	Intel	Corp. headquarters
(7)	Texas Instruments	Yes	Yes	12,695	12,668	3,180	2,989	Texas Instruments	Corp. headquarters
(8)	Xerox	Yes	Yes	12,636	12,635	4,402	3,761	Xerox	Corp. headquarters
(9)	E.I. du Pont de Nemours	Yes	Yes	11,198	10,700	6,967	9,343	E.I. du Pont de Nemours	Corp. headquarters
(10)	3M	Yes	Yes	10,806	10,640	8,796	501	3M	Corp. headquarters
(11)	General Motors	Yes	Yes	9,392	9,275	1,643	162	General Motors	Corp. headquarters
(12)	Hewlett Packard	Yes	Yes	9,150	9,028	5,181	2,042	Hewlett Packard	Corp. headquarters
(13)	Advanced Micro Systems	Yes	Yes	8,466	8,466	685	518	Advanced Micro Systems	Corp. headquarters
(14)	Ford Motor	Yes	Yes	7,349	7,321	1,586	2,653	Ford	Corp. headquarters
(15)	Procter & Gamble	Yes	Yes	7,522	6,417	8,463	2,534	Procter & Gamble	Corp. headquarters
(16)	Microsoft	Yes	Yes	5,888	6,864	2,460	660	Microsoft	Corp. headquarters
(17)	Sun Microsystems	Yes	Yes	6,452	5,641	2,193	472	Sun Microsystems	Corp. headquarters
(18)	Boeing	Yes	Yes	6,072	4,981	1,384	1,307	Boeing	Corp. headquarters
(19)	United Technologies	Yes	Yes	7,151	4,297	2,002	6	United Technologies	Corp. headquarters
(20)	Applied Materials	Yes	Yes	3,842	3,842	1,109	0	Applied Materials	Corp. headquarters

Note: This table lists American firms with most patents in the USPTO. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Group public refers to whether the group ultimate owner is publicly-listed.

TABLE 3: *(Cont'd)*

PANEL B. TOP 20 INNOVATING BRITISH FIRMS

	Company name	Firm public	Group public	Total Group Patents USPTO	Patents USPTO	Patents EPO	Publications	Ultimate Owner	Organizational form
(1)	Imperial Chemical Industries	Yes	Yes	4,147	3,178	2,410	0	Imperial Chemical Industries	Corp. headquarters
(2)	Rolls Royce	Yes	Yes	1,288	1,242	805	379	Rolls Royce	Corp. headquarters
(3)	British Telecommunications	Yes	Yes	1,074	1,073	1,848	0	British Telecommunications	Corp. headquarters
(4)	Beecham Group	No	Yes	3,326	743	801	0	GlaxoSmithKline	Wholly-Owned Affiliate
(5)	BOC	Yes	Yes	692	686	504	4	BOC	Corp. headquarters
(6)	British Technology Group	Yes	Yes	590	590	1,201	2	BTG	Corp. headquarters
(7)	BP Chemicals	No	Yes	4,917	583	728	0	BP	Wholly-Owned Affiliate
(8)	Glaxo Group	No	Yes	3,326	506	1,377	0	GlaxoSmithKline	Wholly-Owned Affiliate
(9)	The British Petroleum	Yes	Yes	4,917	499	531	0	BP	Wholly-Owned Affiliate
(10)	SmithKline Beecham	No	Yes	3,326	440	1,101	5	GlaxoSmithKline	Wholly-Owned Affiliate
(11)	Johnson Matthey	Yes	Yes	314	300	384	24	Johnson Metthey	Corp. headquarters
(12)	Merck Sharp & Dohme	No	Yes	4,408	300	323	107	Merck	Wholly-Owned Affiliate
(13)	Smiths Industries	No	Yes	530	293	141	0	Smiths Group	Wholly-Owned Affiliate
(14)	Molins	Yes	Yes	293	287	78	0	Molins	Corp. headquarters
(15)	British Gas	No	Yes	274	274	211	0	Centrica	Wholly-Owned Affiliate
(16)	John Wyeth & Brother	No	Yes	1,957	253	77	7	Wyeth	Wholly-Owned Affiliate
(17)	Renishaw	Yes	Yes	215	214	308	9	Renishaw	Corp. headquarters
(18)	ARM	Yes	Yes	272	184	64	12	ARM	Corp. headquarters
(19)	BAE Systems	Yes	Yes	490	128	282	0	BAE Systems	Corp. headquarters
(20)	Qinetiq	Yes	Yes	245	122	489	0	Qinetiq	Corp. headquarters

Note: This table lists British firms with most patents in the USPTO. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Group public refers to whether the group ultimate owner is publicly-listed.

TABLE 3: *(Cont'd)*

PANEL C. TOP 20 INNOVATING FRENCH FIRMS

	Company name	Firm public	Group public	Total Group Patents USPTO	Patents USPTO	Patents EPO	Publications	Ultimate Owner	Organizational form
(1)	L'Oreal	Yes	Yes	4,882	3,135	4,066	0	Nestlé	Partly-Owned Affiliate
(2)	Thales	Yes	No	2,652	2,604	3,438	0	TSA	Partly-Owned Affiliate
(3)	Valeo	Yes	Yes	890	586	291	1	Valeo	Corp. headquarters
(4)	France Telecom	Yes	Yes	543	525	1,839	1	France Telecom	Corp. headquarters
(5)	Thomson Licensing	No	Yes	536	498	2,671	0	Thomson	Wholly-Owned Affiliate
(6)	Hutchinson	No	Yes	383	259	509	1	Total	Wholly-Owned Affiliate
(7)	Rhone Poulnec Biochimie	No	Yes	6,465	187	6	0	Sanofi Aventis	Wholly-Owned Affiliate
(8)	Automobiles Peugeot	No	No	219	150	1,177	0	ETS Peugeot-Frères	Partly-Owned Affiliate
(9)	Valois	No	Yes	203	128	248	0	Aptargroup	Wholly-Owned Affiliate
(10)	ELA Medical	No	No	245	123	96	0	Fingruppo	Partly-Owned Affiliate
(11)	Airbus France	No	Yes	565	112	353	9	Lagardere	Partly-Owned Affiliate
(12)	Nexans	Yes	Yes	131	105	344	0	Nexans	Corp. headquarters
(13)	Saint Gobain Glass France	No	Yes	469	102	475	0	Saint Gobain	Wholly-Owned Affiliate
(14)	Kuhn	No	Yes	121	95	279	0	Bucher Industries	Wholly-Owned Affiliate
(15)	Gaz De France	Yes	Yes	88	88	211	2	Gaz De France	Corp. headquarters
(16)	Valeo Vision	No	Yes	890	84	598	0	Valeo	Wholly-Owned Affiliate
(17)	Somfy	No	No	91	82	219	0	J.P.J Holding company	Partly-Owned Affiliate
(18)	Valeo Equipment Electriques Moteur	No	Yes	890	81	296	0	Valeo	Wholly-Owned Affiliate
(19)	Transgene	Yes	No	67	67	137	331	TSGH	Partly-Owned Affiliate
(20)	Gemplus	No	Yes	68	64	325	9	Gemalto	Partly-Owned Affiliate

Note: This table lists French firms with most patents in the USPTO. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Group public refers to whether the group ultimate owner is publicly-listed.

TABLE 3: *(Cont'd)*

PANEL D. TOP 20 INNOVATING GERMAN FIRMS

	Company name	Firm public	Group public	Total Group Patents USPTO	Patents USPTO	Patents EPO	Publications	Ultimate Owner	Organizational form
(1)	Siemens	Yes	Yes	31,999	29,156	52,566	4,263	Siemens	Corp. headquarters
(2)	Robert Bosch Stiftung	No	No	10,437	10,437	13,832	10	Robert Bosch Stiftung	Corp. headquarters
(3)	Bayer	Yes	Yes	11,501	9,969	10,913	0	Bayer	Corp. headquarters
(4)	BASF	Yes	Yes	9,659	9,009	11,331	2,654	BASF	Corp. headquarters
(5)	Hoechst	No	Yes	6,465	5,364	5,868	2,600	Sanofi Aventis	Wholly-Owned Affiliate
(6)	Infineon Technologies	Yes	Yes	4,107	3,914	4,044	0	Infineon Technologies	Corp. headquarters
(7)	DaimlerChrysler	Yes	Yes	1,903	1,894	2,241	7	Daimler	Wholly-Owned Affiliate
(8)	Heidelberger Druckmaschinen	Yes	Yes	1,755	1,748	1,138	4	Heidelberger Druckmaschinen	Corp. headquarters
(9)	Henkel	Yes	Yes	1,565	1,438	4,008	14	Henkel	Corp. headquarters
(10)	Atecs Mannesmann	No	Yes	1,408	1,408	1,186	0	Vodafone	Wholly-Owned Affiliate
(11)	Porsche	Yes	Yes	1,492	903	26	4	Porsche	Wholly-Owned Affiliate
(12)	ZF Friedrichshafen	No	No	881	865	1,031	6	Zeppelin Stiftung	Partly-Owned Affiliate
(13)	Man Roland Druckmaschinen	No	Yes	928	822	1,263	1	Allianz SE	Partly-Owned Affiliate
(14)	Wacker Chemie	Yes	No	922	728	1,019	0	Dr Alexander Wacker	Partly-Owned Affiliate
(15)	BMW	Yes	Yes	708	708	2,866	0	BMW	Corp. headquarters
(16)	Freudenberg	No	No	584	584	530	0	Freudenberg Group	Corp. headquarters
(17)	Schering	No	Yes	11,501	552	1,116	2,217	Bayer	Wholly-Owned Affiliate
(18)	Degussa	No	Yes	630	548	894	6	RWE	Partly-Owned Affiliate
(19)	Alfred Teves	No	Yes	698	485	80	0	Continental	Wholly-Owned Affiliate
(20)	Volkswagen	Yes	Yes	1,492	440	0	140	Porsche	Partly-Owned Affiliate

Note: This table lists German firms with most patents in the USPTO. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Group public refers to whether the group ultimate owner is publicly-listed.

TABLE 3: *(Cont'd)*

PANEL E. TOP 20 INNOVATING ITALIAN FIRMS

	Company name	Firm public	Group public	Total Group Patents USPTO	Patents USPTO	Patents EPO	Publications	Ultimate Owner	Type of Ownership
(1)	STMicroelectronics	No	Yes	2,002	1,370	2,544	0	STMicroelectronics	Wholly-Owned Affiliate
(2)	Montedison	No	Yes	452	396	251	88	Edison	Wholly-Owned Affiliate
(3)	Biofarmitalia	No	No	336	336	148	0	Biofarmitalia	Stand Alone
(4)	Fiat Auto	No	No	306	237	784	7	Giovanni Agnelli & C.	Partly-Owned Affiliate
(5)	Gruppo Lepetit	No	Yes	6,465	133	67	46	Sanofi Aventis	Partly-Owned Affiliate
(6)	Zambon Group	No	No	108	108	121	1	Zambon	Corp. headquarters
(7)	GD	No	No	96	96	123	0	GD	Corp. headquarters
(8)	Indena	No	No	94	93	134	62	IdB Holding	Wholly-Owned Affiliate
(9)	SKF Industrie	No	Yes	345	57	115	0	SKF	Wholly-Owned Affiliate
(10)	Arturo Salice	No	No	47	47	125	0	Giorgio E Luicano Salice	Wholly-Owned Affiliate
(11)	Solvay Solexis	No	Yes	253	45	273	2	Solvac	Partly-Owned Affiliate
(12)	Chiesi Farmaceutici	No	No	46	45	116	3	Chiesi Farmaceutici	Corp. headquarters
(13)	Snamprogetti	No	Yes	163	37	47	91	Eni	Wholly-Owned Affiliate
(14)	Claber	No	No	37	37	1	0	Claber	Stand Alone
(15)	Dideco	No	No	245	33	26	11	Fingruppo	Partly-Owned Affiliate
(16)	Magneti Marelli PowerTrain	No	No	306	32	126	0	Giovanni Agnelli & C.	Partly-Owned Affiliate
(17)	Lonati	No	No	66	32	42	0	Lonati	Corp. headquarters
(18)	Italfarmaco	No	No	34	31	31	41	Italfarmaco Holding	Wholly-Owned Affiliate
(19)	Eni	Yes	Yes	163	30	123	5	Eni	Corp. headquarters
(20)	ACRAF	No	No	30	29	49	0	APO Conerpo	Partly-Owned Affiliate

Note: This table lists German firms with most patents in the USPTO. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Group public refers to whether the group ultimate owner is publicly-listed.

TABLE 4:

ORGANIZATIONAL FORM ACROSS TECHNOLOGY AREAS

Ultimate Owner Country	*Stand Alone*	*Corporate headquarters*	*Affiliates*			*Total*
			All affiliates	Wholly-owned	Partly-owned	
			Pharmaceuticals			
Continental Europe	221.2	426.0	2,425.6	1,528.8	896.9	3,072.8
	(7%)	(14%)	(79%)	(50%)	(29%)	
Great Britain	14.0	148.8	697.8	692.1	5.7	860.6
	(2%)	(17%)	(81%)	(80%)	(1%)	
United States	1,619.7	3,705.5	1,272.7	1,241.6	31.1	6,597.9
	(25%)	(56%)	(19%)	(19%)	(0%)	
Toal	1,854.8	4,280.3	4,396.1	3,462.5	933.6	10,531.2
	(18%)	(41%)	(42%)	(33%)	(9%)	
			Biotechnology			
Continental Europe	26.4	101.7	484.2	354.7	129.5	612.4
	(4%)	(17%)	(79%)	(58%)	(21%)	
Great Britain	6.4	27.6	118.1	117.8	0.2	152.1
	(4%)	(18%)	(78%)	(77%)	(0%)	
United States	523.8	795.3	383.8	368.1	15.7	1,702.9
	(31%)	(47%)	(23%)	(22%)	(1%)	
Toal	556.6	924.7	986.1	840.6	145.5	2,467.4
	(23%)	(37%)	(40%)	(34%)	(6%)	
			Chemicals			
Continental Europe	135.7	1,193.3	1,228.1	903.8	324.3	2,557.1
	(5%)	(47%)	(48%)	(35%)	(13%)	
Great Britain	1.5	487.6	388.6	388.6	0.0	877.7
	(0%)	(56%)	(44%)	(44%)	(0%)	
United States	606.8	2,427.3	1,279.5	1,253.1	26.5	4,314
	(14%)	(56%)	(30%)	(29%)	(1%)	
Toal	743.9	4,108.2	2,896.2	2,545.5	350.8	7,748.4
	(10%)	(53%)	(37%)	(33%)	(5%)	
			Transportation & Engineering			
Continental Europe	740.1	3,159.3	4,156.3	2,699.8	1,456.5	8,055.6
	(9%)	(39%)	(52%)	(34%)	(18%)	
Great Britain	445.5	195.2	681.5	674.1	7.5	1,322.2
	(34%)	(15%)	(52%)	(51%)	(1%)	
United States	6,722.1	13,416.7	5,161.6	5,119.7	41.9	25,300
	(27%)	(53%)	(20%)	(20%)	(0%)	
Toal	7,907.7	16,771.1	9,999.4	8,493.6	1,505.8	34,678.2
	(23%)	(48%)	(29%)	(24%)	(4%)	

Notes: This table examines the distribution of organizational form across technology areas that are characterized as having a strong intellectual property regime and a relatively long and fundamental innovation cycle. Classification of patents to technology areas is based on the International Patent Classification system. Patents are from the USPTO and weighted by the number of citations received. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 4: *(Cont'd)*

ORGANIZATIONAL FORM ACROSS TECHNOLOGY AREAS

Ultimate Owner Country	*Stand Alone*	*Corporate headquarters*	*Affiliates*			Total
			All affiliates	Wholly-owned	Partly-owned	
Telecommunications						
Continental Europe	113.2	1,791.2	3,693.1	3,504.5	188.6	5,597.5
	(2%)	(32%)	(66%)	(63%)	(3%)	
Great Britain	63.6	2.7	127.2	126.4	0.8	193.6
	(33%)	(1%)	(66%)	(65%)	(0%)	
United States	4,878.3	14,284.5	2,641.1	2,604.6	36.5	21,804
	(22%)	(66%)	(12%)	(12%)	(0%)	
Toal	5,055.1	16,078.4	6,461.4	6,235.5	226.0	27,594.9
	(18%)	(58%)	(23%)	(23%)	(1%)	
Information Technology						
Continental Europe	107.3	1,555.4	2,617.2	2,461.5	155.7	4,279.9
	(3%)	(36%)	(61%)	(58%)	(4%)	
Great Britain	311.5	48.1	362.8	360.9	1.9	722.4
	(43%)	(7%)	(50%)	(50%)	(0%)	
United States	10,127.2	59,439.3	6,099.9	5,995.6	104.3	75,666.4
	(13%)	(79%)	(8%)	(8%)	(0%)	
Toal	10,546.0	61,042.8	9,079.9	8,818.0	261.9	80,668.7
	(13%)	(76%)	(11%)	(11%)	(0%)	
Electricity						
Continental Europe	750.4	5,033.0	6,053.2	5,423.7	629.5	11,836.6
	(6%)	(43%)	(51%)	(46%)	(5%)	
Great Britain	181.7	84.1	604.1	604.1	0.0	869.8
	(21%)	(10%)	(69%)	(69%)	(0%)	
United States	11,099.4	38,462.8	4,998.9	4,936.0	62.9	54,561.1
	(20%)	(70%)	(9%)	(9%)	(0%)	
Toal	12,031.5	43,579.9	11,656.2	10,963.8	692.4	67,267.5
	(18%)	(65%)	(17%)	(16%)	(1%)	
Semiconductors						
Continental Europe	202.3	1,970.0	1,194.5	954.4	240.1	3,366.8
	(6%)	(59%)	(35%)	(28%)	(7%)	
Great Britain	40.1	15.3	133.4	131.7	1.7	188.9
	(21%)	(8%)	(71%)	(70%)	(1%)	
United States	3,247.7	28,358.0	1,093.8	1,061.1	32.7	32,699.4
	(10%)	(87%)	(3%)	(3%)	(0%)	
Toal	3,490.1	30,343.3	2,421.7	2,147.2	274.5	36,255.1
	(10%)	(84%)	(7%)	(6%)	(1%)	

Notes: This table examines the distribution of organizational form across main technology areas that are characterized as having a weak intellectual property regime and a relatively complex and short innovation cycle. Classification of patents to technology areas is based on the International Patent Classification system. Patents are from the USPTO and weighted by the number of citations received. A firm is classified as a standalone if it has no equity ties to other firms, as a corporate headquarters if it holds equity stakes in other companies, as a wholly-owned affiliate if it has a parent company that owns 100% of its shares, and as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner.

TABLE 5:

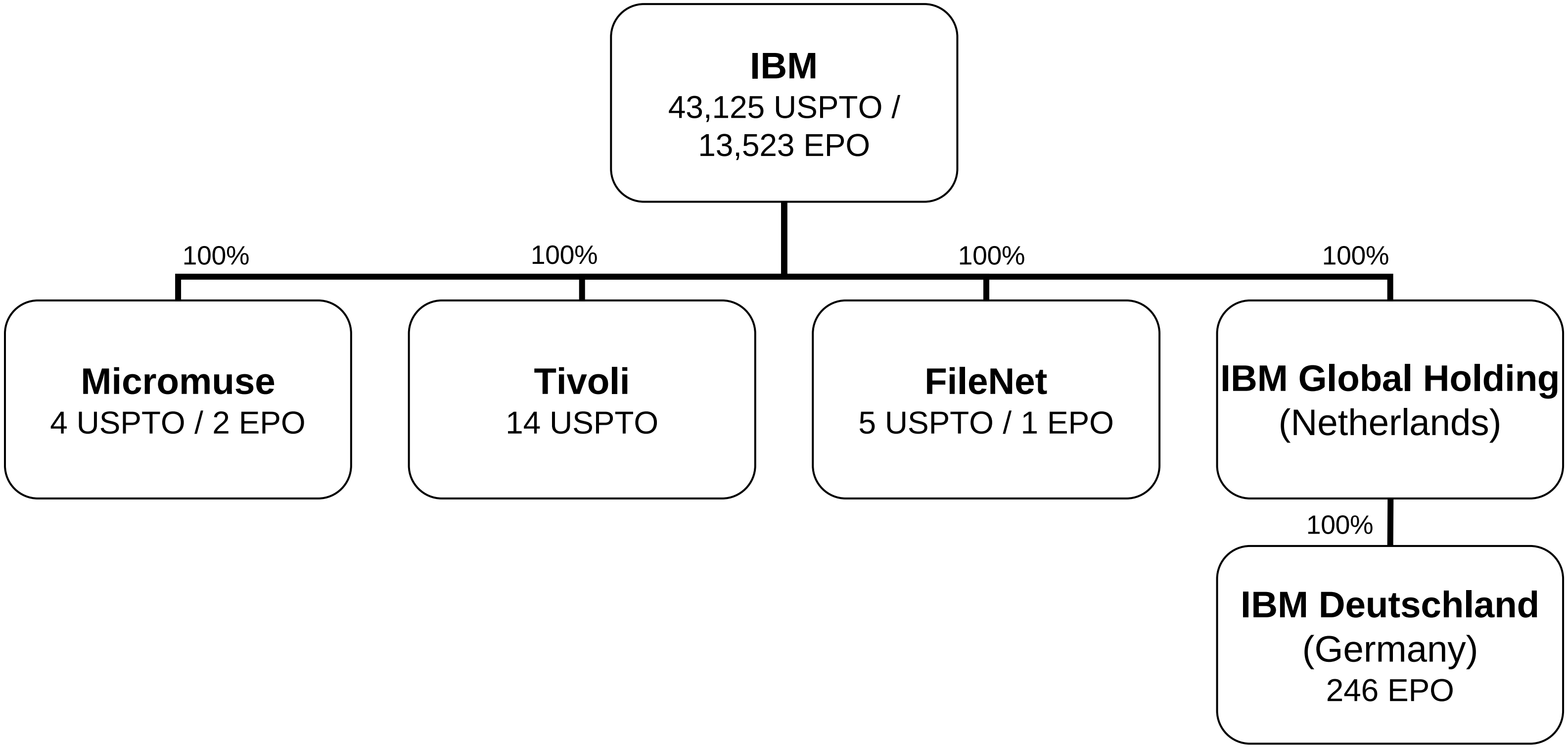
THE EFFECT OF COUNTRY AND INDUSTRY LOCATION ON PARTLY-OWNED AFFILIATION

Dependent variable: Dummy for Minority Shareholders. Linear Probability Model

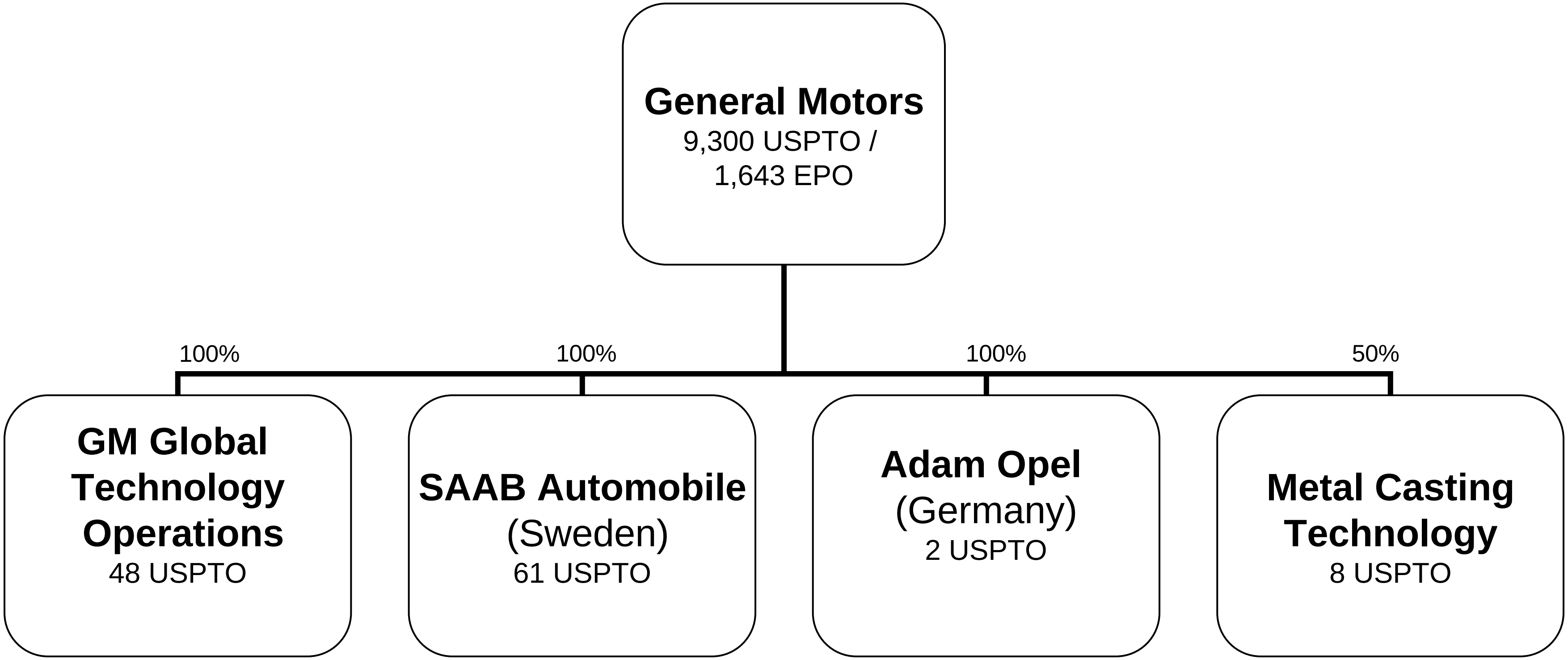
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Firms:	All	All	All	Cites ≤ 25th	Cites > 75th	Age ≤ 25th	Age > 75th	All	Cites ≤ 25th	Cites > 75th
Dummy for Con. Europe	0.132***	0.126***								
	(0.039)	(0.046)								
Dummy for Great Britain	0.013	0.010	0.010	0.006	0.004	0.024	-0.007			
	(0.017)	(0.015)	(0.014)	(0.017)	(0.005)	(0.027)	(0.009)			
Dummy for Germany			0.135***	0.136***	0.108***	0.133***	0.128***			
			(0.046)	(0.045)	(0.040)	(0.050)	(0.044)			
Dummy for France			0.240***	0.252***	0.186***	0.352***	0.157***			
			(0.097)	(0.094)	(0.075)	(0.121)	(0.056)			
Dummy for Italy			0.350***	0.319***	0.473***	0.430***	0.302***			
			(0.104)	(0.094)	(0.145)	(0.137)	(0.093)			
Dummy for Other Europeans			0.215*	0.215**	0.145*	0.279*	0.172**			
			(0.117)	(0.109)	(0.087)	(0.153)	(0.089)			
Dummy for Con. Europe interacted with:										
Dummy for Pharmacueticals								0.539***	0.508***	0.514***
								(0.212)	(0.201)	(0.217)
Dummy for Biotechnology								0.355***	0.389***	0.315***
								(0.146)	(0.150)	(0.145)
Dummy for Chemicals								0.216**	0.225***	0.175**
								(0.091)	(0.093)	(0.085)
Dummy for Electronics								-0.005***	-0.009***	-0.001**
								(0.002)	(0.004)	(0.0005)
Dummy for Transportation								0.016*	0.020*	0.009
								(0.009)	(0.012)	(0.007)
Dummy for Information Technology								-0.005***	-0.009***	-0.002**
								(0.002)	(0.003)	(0.001)
Dummy for Telecommunications								-0.006***	-0.010***	0.010
								(0.002)	(0.004)	(0.007)
Dummy for Other Industries								0.113***	0.121***	0.085***
								(0.036)	(0.037)	(0.029)
log(Sales)		-0.002**	-0.002**	-0.001	-0.0013***	-0.002**	-0.001	-0.001	-0.001	-0.001***
		(0.001)	(0.001)	(0.001)	(0.0003)	(0.001)	(0.001)	(0.001)	(0.001)	(0.0002)
log(Age)		-0.002	-0.002	-0.005	-0.001	-0.001	-0.003	-0.003	-0.005*	-0.001
		(0.002)	(0.002)	(0.003)	(0.001)	(0.001)	(0.002)	(0.002)	(0.003)	(0.001)
Predicted Probability, Mean	0.009	0.006	0.007	0.011	0.002	0.004	0.009	0.006	0.010	0.002
R^2	0.272	0.301	0.304	0.277	0.360	0.360	0.273	0.350	0.317	0.411
No. of patents	499,675	499,675	499,675	201,140	123,691	272,400	227,281	499,685	201,140	123,691

Note: This table reports the estimation results of the effect of country and industry dummies on the probability that a patent belongs to a partly-owned affiliate firms for a sample of USPTO patents that were granted in the period 1975-2007. We include firms that have, on average, at least 20 employees and generate at least $1 million in annual sales. Assignment of firms to countries is based on the nationality of the ultimate owner. A firm is classified as a partly-owned affiliate if it has minority shareholders in addition to its controlling ultimate owner. Regressions include a complete set of patent grant year dummies and a dummy for publicly-listed firms (excluding column 1). Firm age refers to the age of the firm at the grant year of the patent (where firm age is the number of years from the year of incorporation). Standard errors (in brackets) are robust to arbitrary heteroskedasticity and allow for serial correlation through clustering by firms. * significant at 10%; ** significant at 5%; *** significant at 1%.

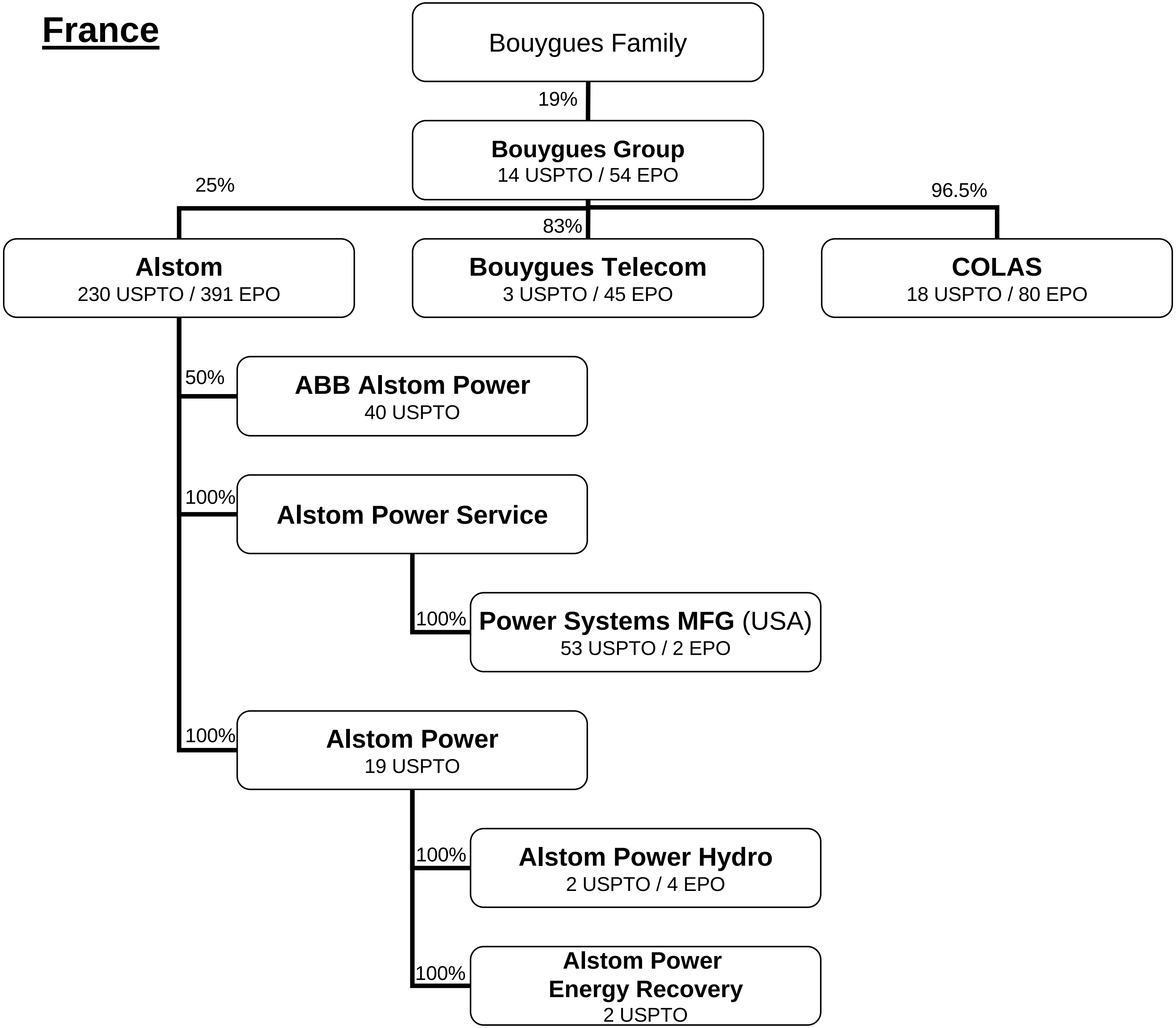
United States



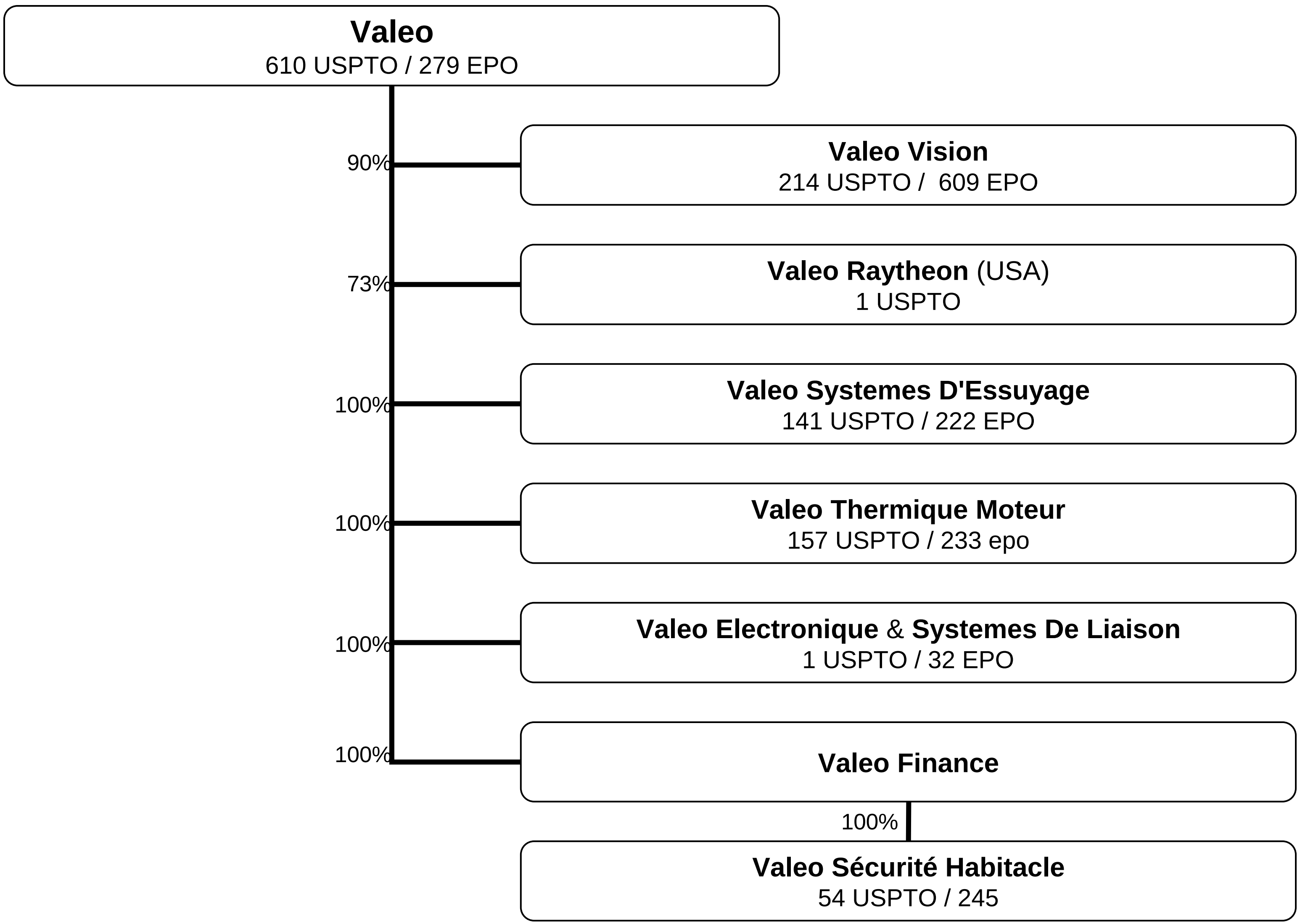
United States



France

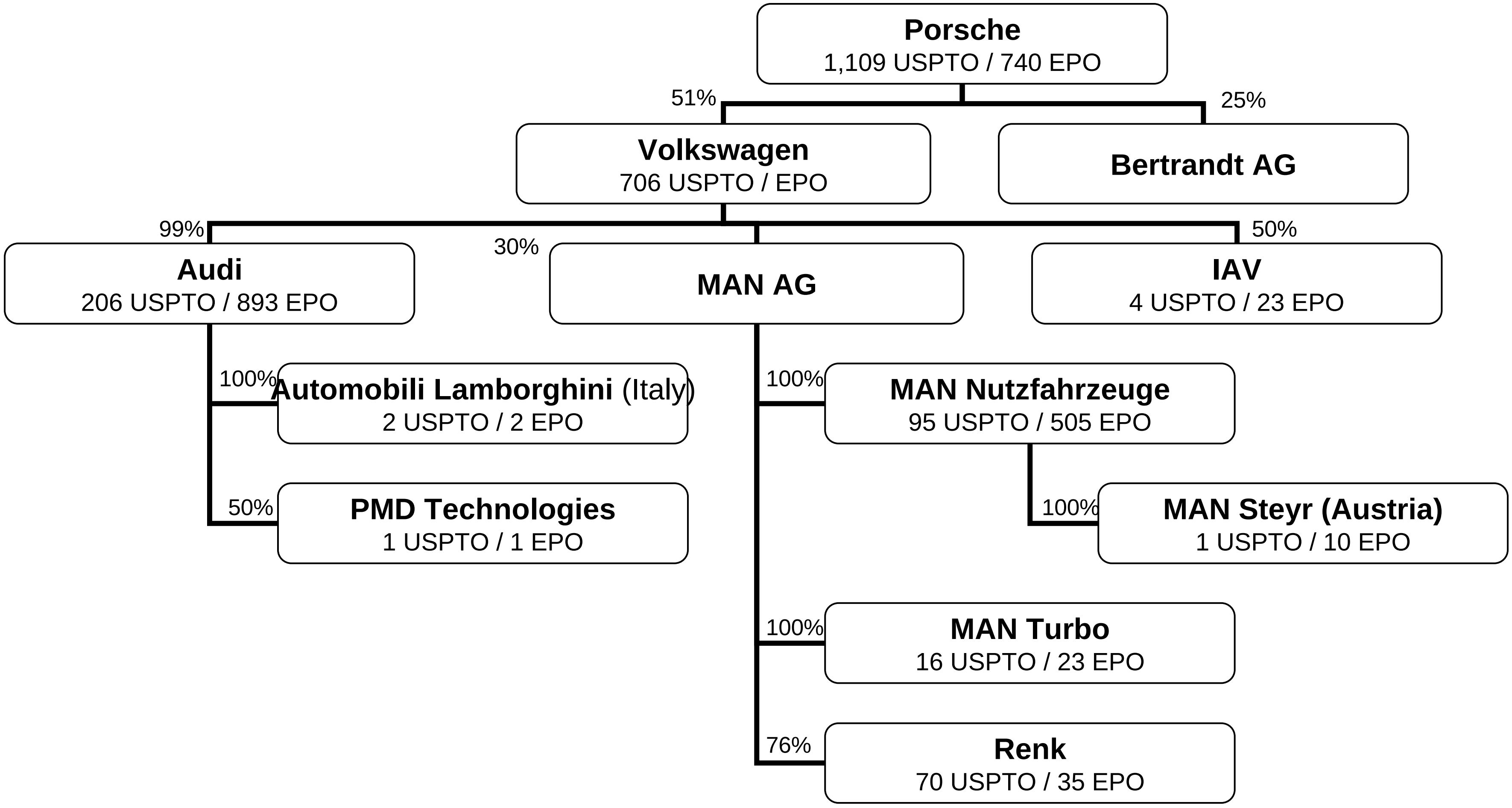

Bouygues Family
19%
Bouygues Group
14 USPTO / 54 EPO
25%
83%
96.5%
Alstom
230 USPTO / 391 EPO
Bouygues Telecom
3 USPTO / 45 EPO
COLAS
18 USPTO / 80 EPO
50%
ABB Alstom Power
40 USPTO
100%
Alstom Power Service
100%
Power Systems MFG (USA)
53 USPTO / 2 EPO
100%
Alstom Power
19 USPTO
100%
Alstom Power Hydro
2 USPTO / 4 EPO
100%
Alstom Power
Energy Recovery
2 USPTO

France



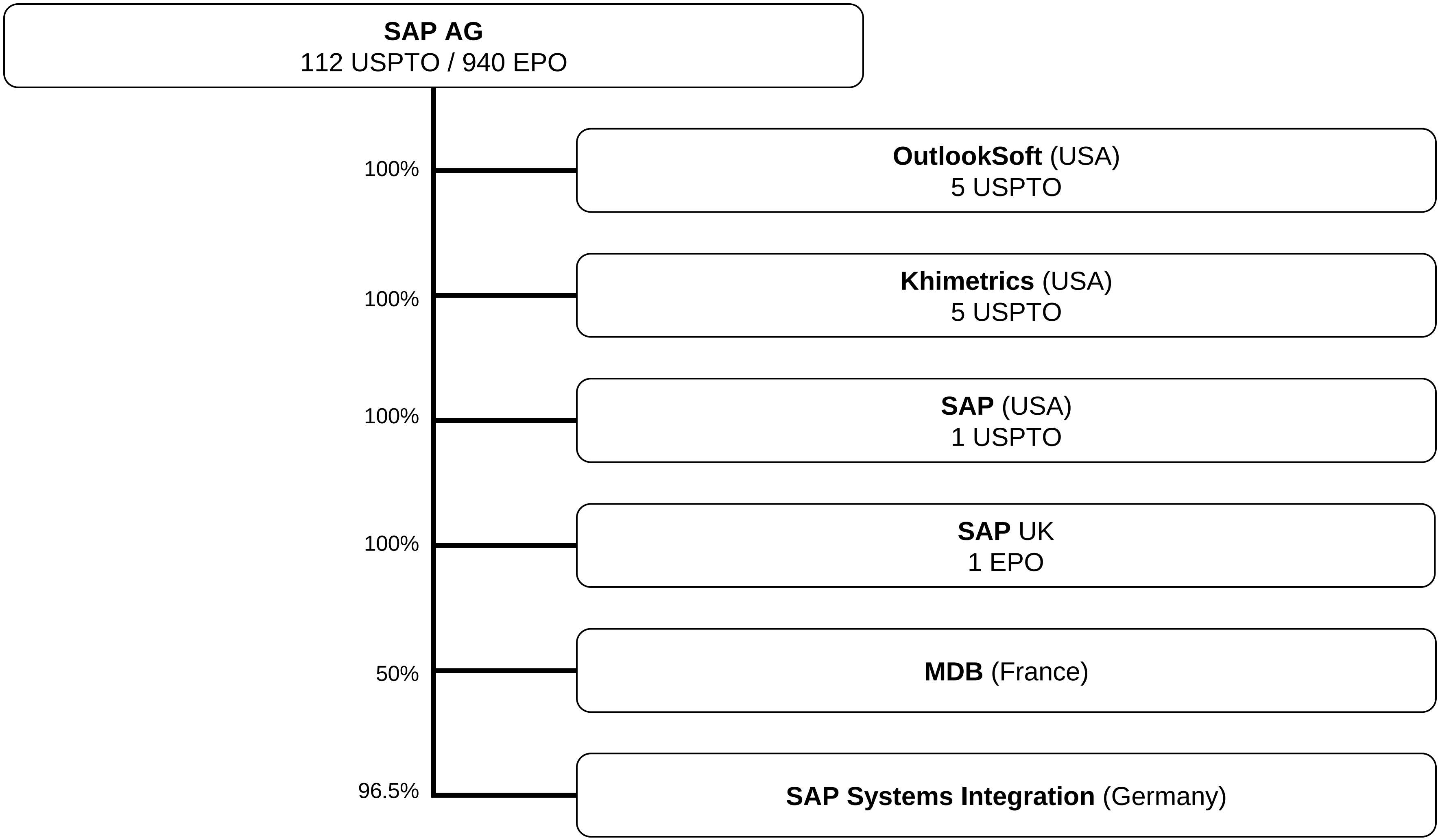
Valeo
610 USPTO / 279 EPO
90%
Valeo Vision
214 USPTO / 609 EPO
73%
Valeo Raytheon (USA)
1 USPTO
100%
Valeo Systemes D'Essuyage
141 USPTO / 222 EPO
100%
Valeo Thermique Moteur
157 USPTO / 233 epo
100%
Valeo Electronique & Systemes De Liaison
1 USPTO / 32 EPO
100%
Valeo Finance
100%
Valeo Sécurité Habitacle
54 USPTO / 245

Germany



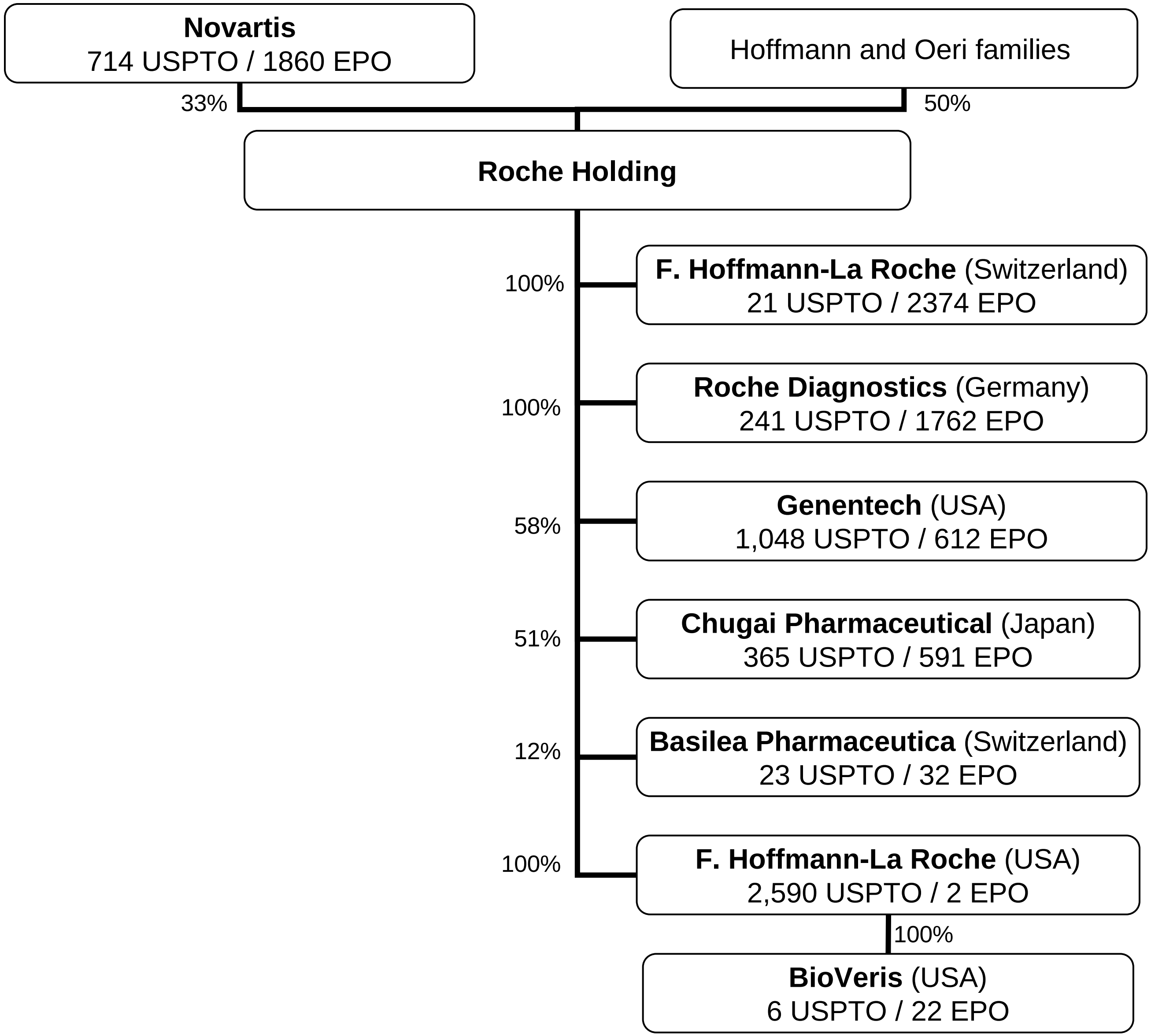
Porsche
1,109 USPTO / 740 EPO
51%
25%
Volkswagen
706 USPTO / EPO
Bertrandt AG
99%
30%
50%
Audi
206 USPTO / 893 EPO
MAN AG
IAV
4 USPTO / 23 EPO
100%
Automobili Lamborghini (Italy)
2 USPTO / 2 EPO
100%
MAN Nutzfahrzeuge
95 USPTO / 505 EPO
50%
PMD Technologies
1 USPTO / 1 EPO
100%
MAN Steyr (Austria)
1 USPTO / 10 EPO
100%
MAN Turbo
16 USPTO / 23 EPO
76%
Renk
70 USPTO / 35 EPO

Germany

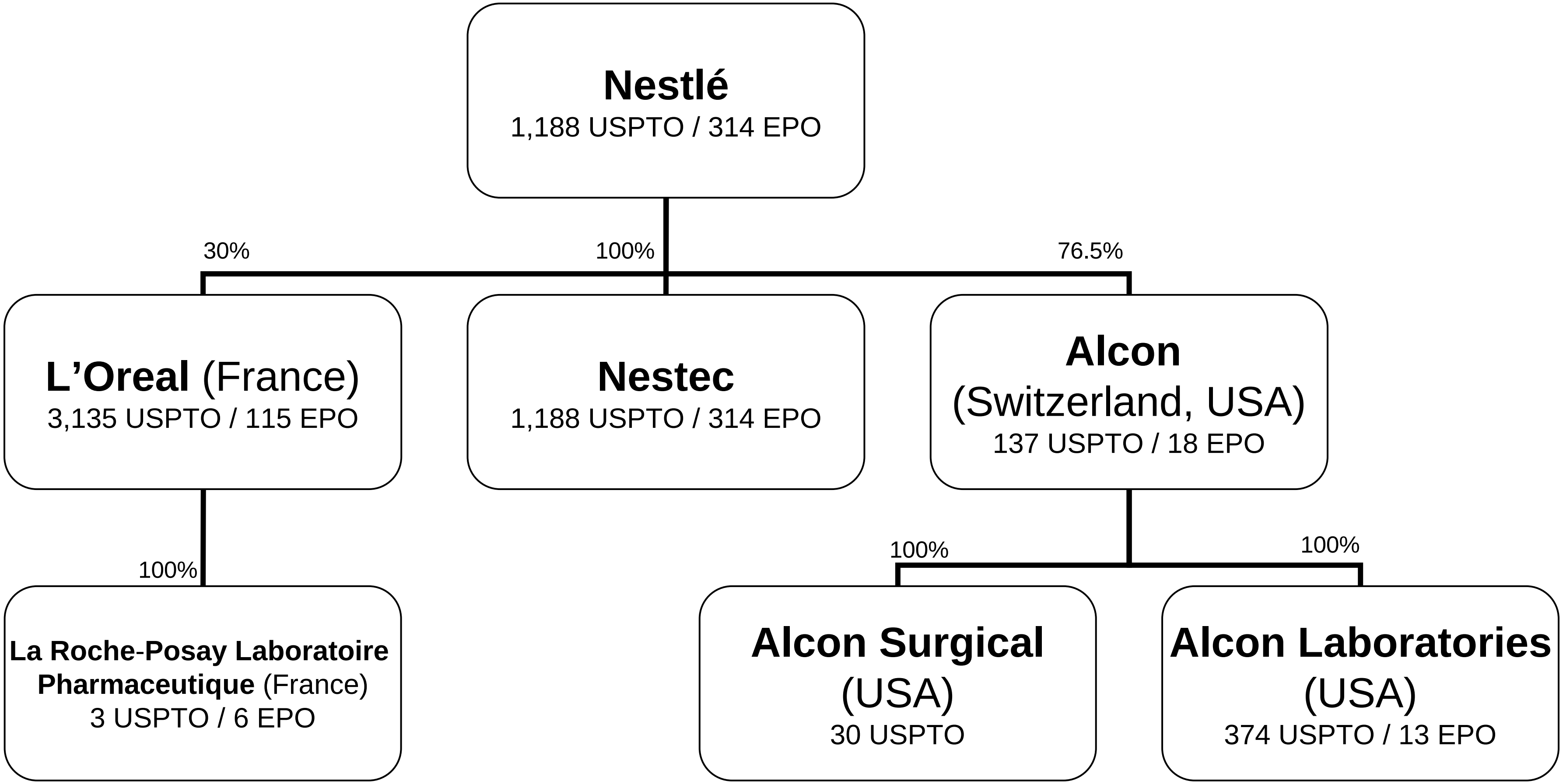


SAP AG
112 USPTO / 940 EPO
100%
OutlookSoft (USA)
5 USPTO
100%
Khimetrics (USA)
5 USPTO
100%
SAP (USA)
1 USPTO
100%
SAP UK
1 EPO
50%
MDB (France)
96.5%
SAP Systems Integration (Germany)

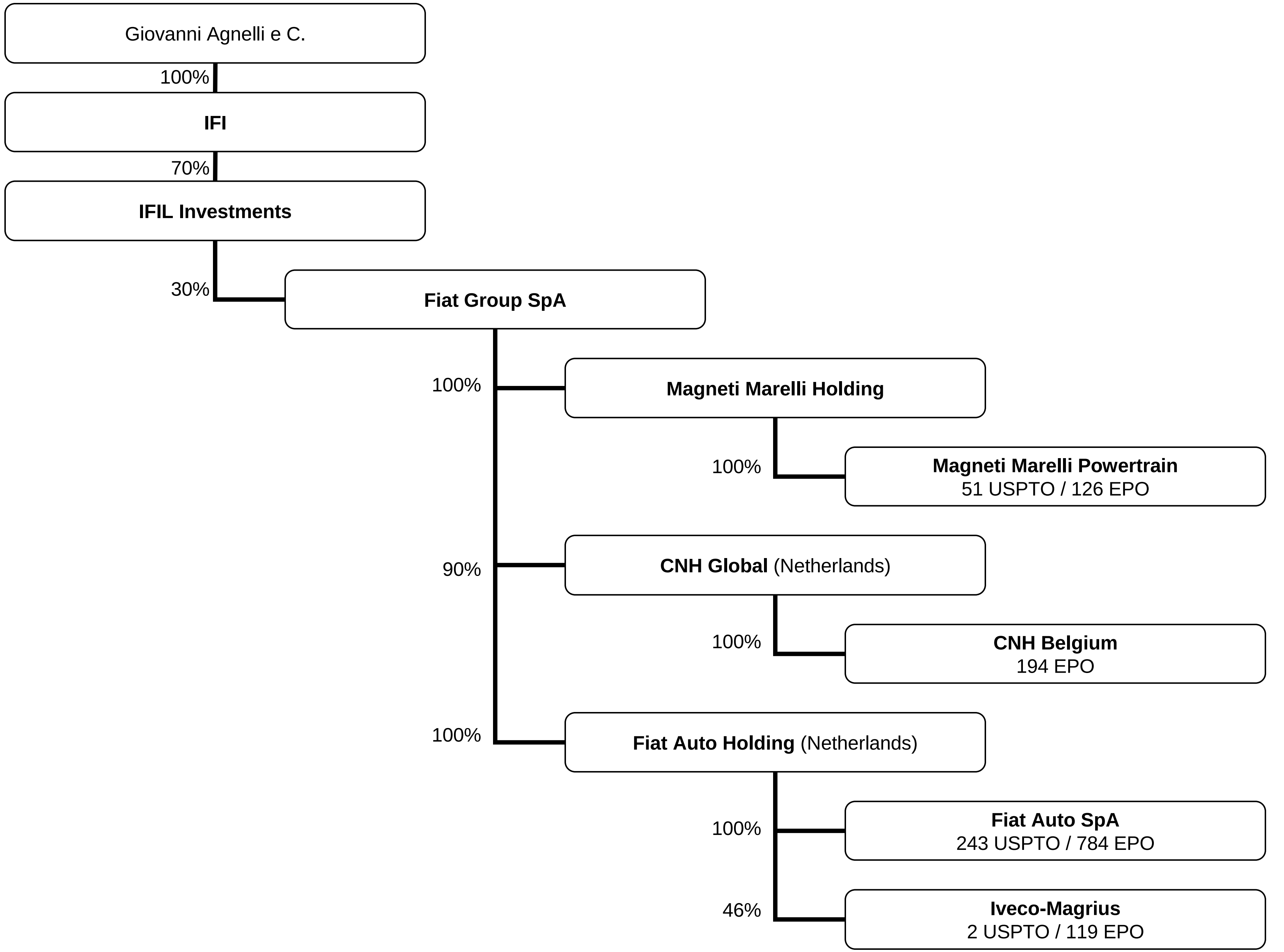
Switzerland



Switzerland

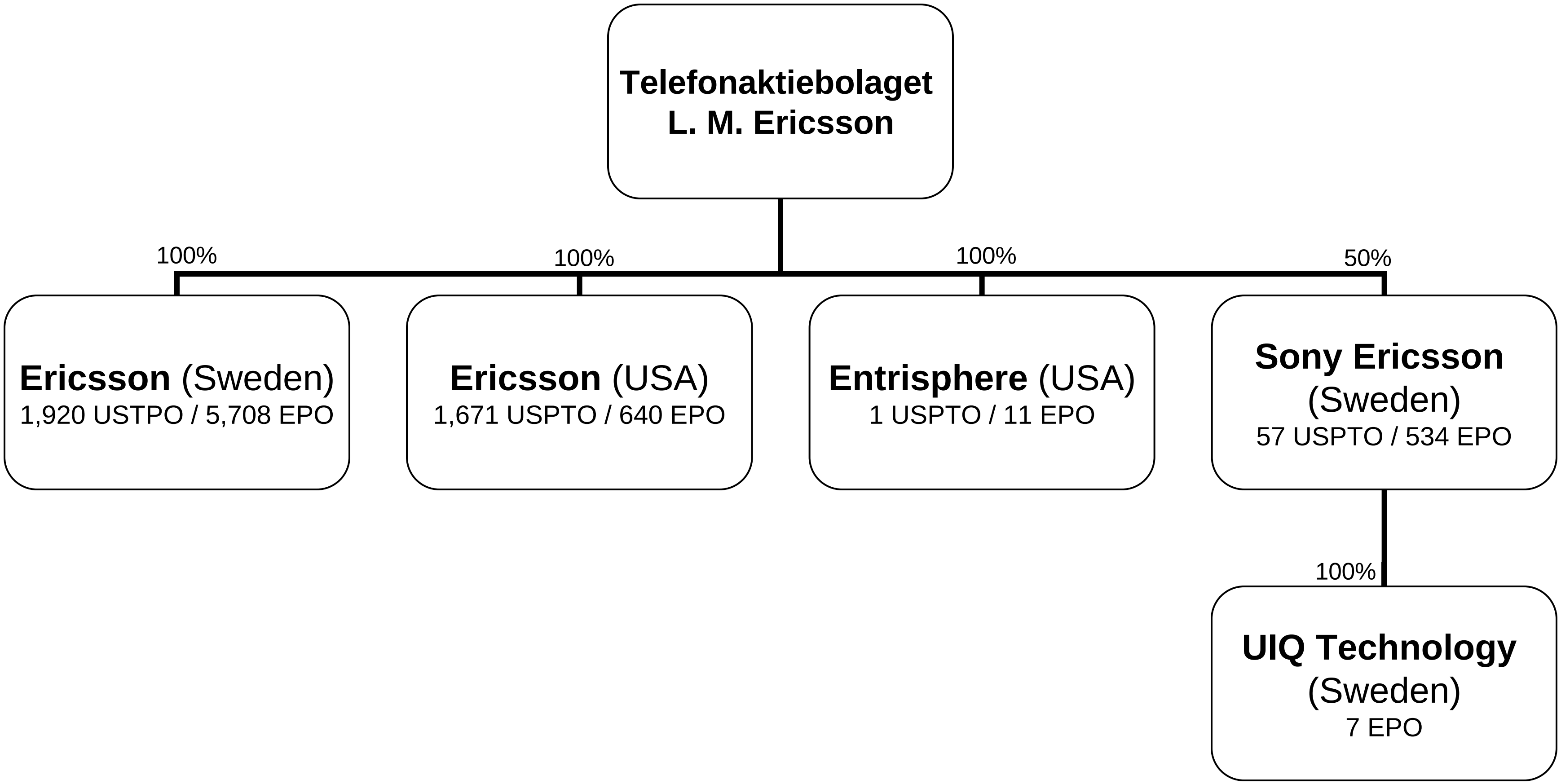


Italy

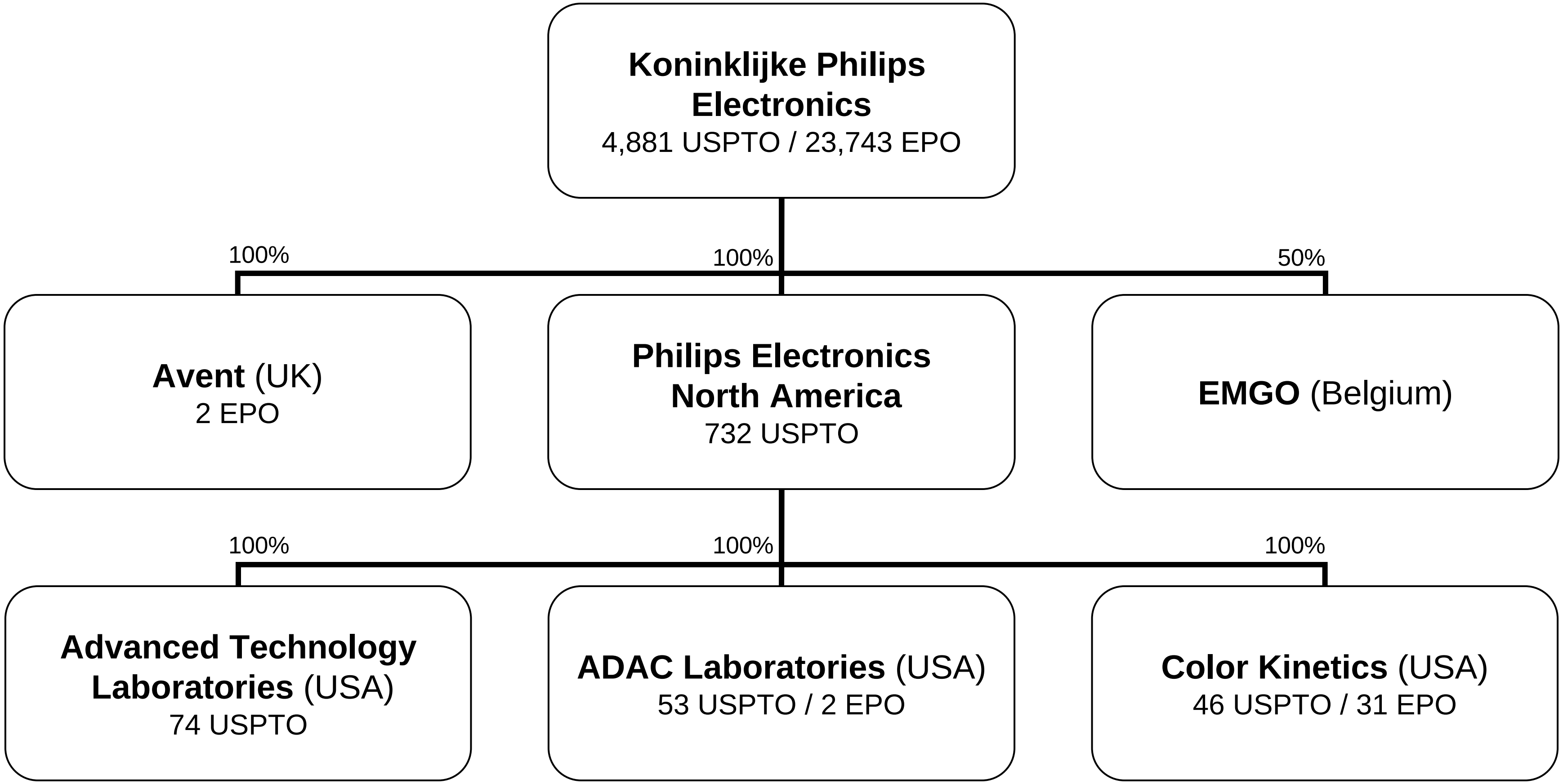


Giovanni Agnelli e C.
100%
IFI
70%
IFIL Investments
30%
Fiat Group SpA
100%
Magneti Marelli Holding
100%
Magneti Marelli Powertrain
51 USPTO / 126 EPO
90%
CNH Global (Netherlands)
100%
CNH Belgium
194 EPO
100%
Fiat Auto Holding (Netherlands)
100%
Fiat Auto SpA
243 USPTO / 784 EPO
46%
Iveco-Magrius
2 USPTO / 119 EPO

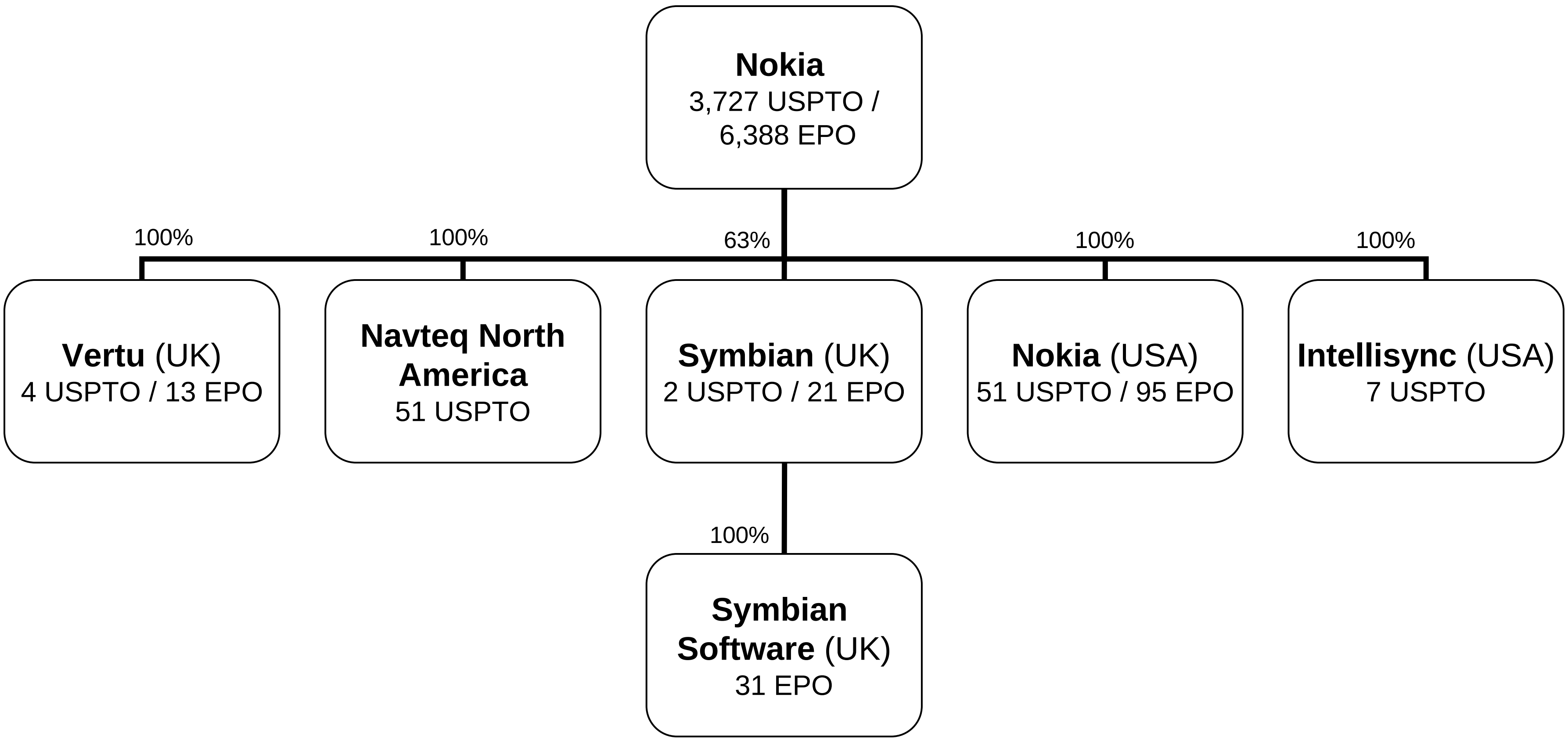
Sweden


Telefonaktiebolaget L. M. Ericsson
100%
100%
100%
50%
Ericsson (Sweden)
1,920 USTPO / 5,708 EPO
Ericsson (USA)
1,671 USPTO / 640 EPO
Entrisphere (USA)
1 USPTO / 11 EPO
Sony Ericsson (Sweden)
57 USPTO / 534 EPO
100%
UIQ Technology (Sweden)
7 EPO

Netherlands



Finland



Nokia
3,727 USPTO / 6,388 EPO
100%
100%
63%
100%
100%
Vertu (UK)
4 USPTO / 13 EPO
Navteq North America
51 USPTO
Symbian (UK)
2 USPTO / 21 EPO
Nokia (USA)
51 USPTO / 95 EPO
Intellisync (USA)
7 USPTO
100%
Symbian Software (UK)
31 EPO