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Decentralization of the firm: theory and evidence

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Abstract

Value maximization requires either that knowledge is transferred to those with the right to make decisions, or that decision rights are transferred to those who have the knowledge. A tradeoff of knowledge transfer costs and control costs is required. Characteristics of firms' investment opportunity sets (IOSs) that affect knowledge transfer costs and control costs are identified. Testable predictions about the relations between these characteristics and firms' decentralization decisions are developed and tested. The evidence presented is consistent with our predictions and is robust to different ways of measuring variables.

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1. Introduction

The relation between decentralization of decision rights within firms and observable characteristics of firms' investment opportunity sets (IOSs) is investigated. The level of decentralization (delegation) investigated is from the CEO to the next management level

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below the CEO.[1] The relative use of profit and cost centers at that level is used to represent decentralization. The firm' characteristics used in empirical work are the specialization of knowledge generated in the firm, externalities and complementarities among the firm's investments, and regulation.[2]

Some measures of these attributes of firms are obtained from a questionnaire, others from public data sources, and some from both. The use of profit and cost centers is robustly related to these characteristics of the firms' investment opportunity sets. Unregulated firms with knowledge that is more costly to transfer to decision makers, and with fewer externalities among the firm's operating units, are more likely to decentralize decision rights by using profit centers. The evidence is that larger firms with growth options that face greater uncertainty generate knowledge that is more costly to transfer to decision makers. The results are invariant to alternative measures of the relevant characteristics of the firm.

One specification uses questionnaire data for the dependent variable only and so can be used to predict decentralization for firms outside the sample. To gain further insight into the empirical model's descriptive ability, this specification is used to predict decentralization of Caterpillar and General Electric. The choice of these firms is explained in Section 6.

The next section discusses the theory, and our measurement of, decentralization. The relation between decentralization and firms' investment opportunity set (IOS) characteristics is discussed in Section 3. Development of empirical measures of those characteristics, and their related descriptive statistics, is in Section 4. Section 5 presents the empirical relations between the decentralization measure and investment opportunity set characteristics. The Caterpillar and General Electric cases are presented in the sixth section, while the final section contains a summary and conclusions.

2. Decentralization of decision rights

Value maximization is more likely to occur if those with the responsibility for decisions have the knowledge valuable to those decisions (Hayek, 1945; Harris et al., 1982; Jensen and Meckling, 1992). Decision rights can be collocated with knowledge by transferring the knowledge to the person who has the decision rights or by transferring the decision rights to the person with the knowledge. The first approach generates knowledge transfer costs and the second generates control costs.

In principle, the theory underlying the decentralization decision is simple. Value is increased by minimizing the total of knowledge transfer costs and control costs. Minimizing this total cost requires allocating some decision rights from the CEO's office to lower levels of the firm. However, neither knowledge transfer costs nor control costs are observable. Further, the knowledge transfer and control cost curves vary over firms and

[1] The term CEO (or CEO's office) refers to all components of the executive office, including the board of directors, chairman, president and any executive vice presidents.

[2] To economize on terminology, we refer to both externalities and complementarities as externalities.

time. We identify observable characteristics of firms' investment opportunity sets that affect knowledge transfer costs and control costs. The remainder of Section 2 discusses knowledge transfer costs, control costs, our measure of decentralization, and the relation of decentralization to other policy choices of the firm.

2.1. Knowledge transfer costs

In part, knowledge transfer costs arise because decision makers have limited mental and sensory faculties (see March and Simon, 1958, or Arrow, 1974). Effective use of knowledge in decisions requires a decision maker to understand the knowledge received. Knowledge transfer costs include out of pocket costs of transmitting the knowledge to the person with the decision rights, losses that arise from delays in this transmission process, and the loss that occurs because the decision maker does not understand the knowledge well enough to act on it in a timely manner. Limits on human capacity ensure that some agents do not have knowledge in common. Such lack of common knowledge is a barrier to communication. Melumad et al. (1992) (MMR) examine delegated decision making when communication between the CEO and other parts of the organization is restricted. MMR show that such restrictions generate a demand for responsibility centers, with accompanying delegation of decision rights. Vaysman (1996) studies the implications of restrictions on communication for choice of transfer pricing methods among responsibility centers.[3]

If knowledge relevant to decisions resides at lower levels of the firm, then decentralization reduces knowledge transfer costs. The CEO has knowledge that lower levels do not and that knowledge is often communicated to lower levels of the firm. The cost of transferring knowledge from the CEO to lower level decision makers reduces the net benefit from decentralization and, everything else equal, results in less decentralization. Athey et al. (1996) study the effects of differences in high and low level knowledge, and the effects of changes in complexity and uncertainty, on allocations of decision rights. Section 4.1 below develops measures of both low and high level knowledge and of uncertainty.

We adopt Demsetz' (1988) term 'specialized' to describe knowledge that is costly to transfer and 'nonspecialized' to refer to knowledge that can be transferred at low cost.[4] We

[3] MMR and Vaysman refer to the benefit from delegating decision rights as the flexibility gain, which is equivalent to a reduction in knowledge transfer costs.

[4] Demsetz (1988) addresses using 'specialized knowledge' to determine the boundaries of the firm rather than in allocating decision rights within the firm; however, we interpret Demsetz' term specialized to be knowledge that is costly to transfer. Demsetz does not discuss other types of knowledge. Kaplan and Atkinson (1989) discuss knowledge transfer costs and control costs and also use the term 'specialized' to describe knowledge that is costly to transfer. Because knowledge that is specific to time and place is costly to transfer, Jensen and Meckling (1992) adopt the term 'specific' to refer to knowledge that is costly to transfer and use the term 'general' to describe knowledge that is not costly to transfer. The term specific is also used to refer to assets or human capital that lose value if not used in the firm, and 'general knowledge' is in common usage to describe political, geographic and current events. Therefore, we use Demsetz' term 'specialized' to describe knowledge that is costly to transfer.

argue below that flows of knowledge (information) are only useful in the context of the existing stock and so use the term knowledge to refer to both stocks and flows of knowledge. Information refers solely to flows.

2.2. Control costs

The costs of transferring decision rights from the CEO to lower levels are control costs. Having lower-level managers make decisions in the owners' (or even the CEO's) interests requires costly systems for measuring and evaluating the lower-level managers' performance, and rewarding or punishing their performance. Residual loss increases also if those systems do not perfectly align the lower-level managers' interests with those of the owners. Decentralization increases control costs.

Control costs increase with the specialization of knowledge. That is, control costs vary positively with knowledge transfer costs. By definition, specialized knowledge is unobservable by the CEO. This additional 'noise' makes it harder to separate the manager's ability and effort from the effects of state variables. It is more difficult for the CEO's office to assess unit managers' decisions that are based on specialized knowledge, irrespective of what causes the knowledge to be specialized. Hence, the costs of controlling unit managers are higher for firms that generate more specialized knowledge. This reduces the tendency for firms generating relatively more specialized knowledge to be more decentralized.

2.3. Measuring decentralization

Allocations of decision rights within firms are complex. Some rights are kept by the CEO's office and others are delegated to lower levels. Also, single decisions can be broken into components, with the executive office handling some parts and others being delegated. For example, investment decisions are often split into initiation, notification, ratification, implementation and monitoring tasks (see Meckling and Jensen, 1986). The lower level is given the right to initiate an investment project, but the executive office keeps the right to ratify the investment decision. This complexity makes modeling decentralization difficult and existing models are necessarily relatively simple.[5]

Assessing the degree of decentralization of a firm is complicated by the multidimensional nature of decentralization. We use an instrumental (unidimensional) variable for the general degree of decentralization from the CEO to the next management level (the 'second level').[6] Our instrument is the relative use of profit and cost centers at the second

[5] For examples of both formal and informal decentralization models see: Chandler (1962, 1977), Williamson (1975), Vancil (1978), Jensen and Meckling (1992), Melumad et al. (1992), Milgrom and Roberts (1992), Radner (1992), Athey et al. (1996) and Vaysman (1996).

[6] Measuring IQ provides an analogy to measuring decentralization. While most agree that IQ is multidimensional, virtually all measures of IQ are unidimensional. Typically, we distinguish quantitative from qualitative skills, but do not measure other human attributes such as persistence or artistic abilities.

level. Williamson (1975) and Vancil (1978) find that profit-center managers typically have a broader set of decision rights than cost-center managers; profit centers are associated with more decentralization. The argument is simple. Cost center managers control either costs or revenues, but not both. Profit center managers make decisions about both revenues and costs.[7]

The decentralization measure is obtained from a questionnaire, which asks the firm's management to identify the second level and tell us whether the second level units are profit centers, cost centers or a mixture of the two. To avoid firms using different interpretations of the second level, we define in the questionnaire what we mean by the second level. The focus is on line units and so excludes functions such as finance and treasury.

The decentralization variable is coded as one for all profit centers, one-half for mixed profit and cost centers, and zero for all cost centers. The results are reported in panel A of Table 1. About 54% of the firms report that their second level of management is organized into profit centers. The rest of the firms' answers are roughly evenly distributed between organization into cost centers and organization into a mixture of profit and cost centers.

2.4. The relation of decentralization to other policy choices by the firm

The decentralization choice (decision right allocations) is only one of the policy choices firms make. Other important choices include performance evaluation and compensation policies, marketing and distribution, production technology, capital structure, dividend policy, hedging, credit policy and accounting policies, such as asset capitalization, inventory method, transfer pricing, budgeting and cost allocations. These corporate policies depend on decision right allocations and on various characteristics of the firm. However, decision right allocations depend on other policies, including performance evaluation and compensation policies, and characteristics of the firm. These characteristics of the firm are collectively referred to as the firm's investment opportunity set (IOS).

The IOS includes the firm's prospective investment opportunities and associated payoff distributions (Smith and Watts, 1992).[8] The IOS also includes the type of knowledge and information generated by the firm, the location of that knowledge within the firm, production and information externalities among the firm's operating units, growth, technological uncertainty, demand uncertainty, regulation (state and federal), type of customer, type of employee (high or low skill), type of assets (physical, specificity, human), product and other tortious liabilities, and tax structure (domestic and foreign); see Christie (2001).

[7] Antle and Demski (1988) treat the choice of cost, revenue and profit centers as a performance evaluation problem. They implicitly assume that managers have unlimited knowledge, and can run cost centers, revenue centers or profit centers. In contrast, we argue that limits on individual knowledge lead to delegation of decision rights to responsibility centers in the spirit of MMR. The performance evaluation system is then matched to the types of responsibility centers chosen (cost, revenue or profit).

[8] Smith and Watts (1992) examine interactions among firms' financing, dividend and compensation policies, and the relation of these policies to the IOS.

Table 1
Empirical distributions of variables 121 CRSP/Compustat firms, 1987 data

Panel A: Variables from the questionnaire

Decentralization (DEC)	Cost Centers	Mixed	Profit Centers	Total	
	25 (21%)	30 (25%)	66 (54%)	121	
Coded	0	0.5	1.0		

Externalities (EXT)	Unrelated Businesses	Related Businesses	Dominant Business	Single Business	Total
	25 (21%)	33 (27%)	28 (23%)	35 (29%)	121

Panel B: Variables as analyzed[a]

	Min.	Mean	Median	Max.	Std. Dev.
Decentralization (DEC)	0.00	0.67	1.00	1.00	0.40
Standardized number of lines of business (NLOB/MAXLOB)	0.03	0.21	0.16	1.00	0.18
Knowledge Specialization ($\overline{\text{KS}}$): Average knowledge specialization for the firm's SIC codes (lines of business)	0.00	0.49	0.60	1.00	0.41
Incremental Knowledge Specialization (ΔKS): SNLOB($1-\overline{\text{KS}}$)	0.00	0.07	0.05	0.55	0.07
Growth (GROW)	0.72	1.26	1.09	3.08	0.45
Uncertainty (UNC)	0.15	0.31	0.30	0.68	0.10
Divisional uncertainty (DUNC): Lines of business dependent	0.15	0.32	0.31	0.72	0.10
Sales (SIZE): Sales divided by the maximum sales	0.00	0.06	0.02	1.00	0.13
Regulation (REG): One if the firm's principal business is regulated, zero otherwise[b]	0.00	0.23	0.00	1.00	0.42

[a] A variable shown as 0.00 may be greater than zero but is less than 0.005.
[b] Utilities, communications and transport firms are considered regulated.

The net effect of this view of firms is that the decentralization decision is an endogenous choice that depends on and affects other policy choices. Therefore, this paper addresses only one of many equations in a simultaneous system; the IOS is predetermined. We provide a variety of econometric diagnostics to address the fact that we only estimate one equation out of a system. We cannot reject the hypothesis that our estimated relations are well specified. The econometric details are in Section 5. The next section discusses the relation of decentralization to the IOS.

3. Knowledge transfer costs, control costs and characteristics of firms

This section discusses IOS characteristics that affect firms' decentralization decisions. These IOS characteristics are the degree of specialization of knowledge created by the firm and the level within the firm at which that knowledge is created, externalities among the firm's investments, and whether the firm is subject to price regulation. Knowledge transfer costs (KTC) affect decentralization both directly and through control costs (CC). Externalities (EXT) affect only control costs, while price regulation (REG) affects decentralization directly. The relations are summarized in the following equation:

$$\mathrm{DEC} = D\ (\mathrm{KTC}, \mathrm{CC}\,(\mathrm{KTC}, \mathrm{EXT}), \mathrm{REG}). \tag{1}$$

Decentralization is increasing in KTC and decreasing in CC and REG. CC are increasing in both KTC and EXT. The theory does not specify functional forms for these relations. However, firms that choose $0 < \mathrm{DEC} < 1$ must have nonlinear cost functions because linear cost functions ensure that DEC is either zero or one. We return to this issue in Section 5.

A key issue is which characteristics of firms cause KTC to vary across firms and through time. We argue that KTC depend on the following: the ability to automate decision making; the ability to aggregate knowledge; technology and changes in technology; competition; demand for product heterogeneity; uncertainty; and firm size.

Some of these IOS characteristics have been previously discussed in the literature on decentralization (Chandler, 1962, 1977; Williamson, 1975; Vancil, 1978; Jensen and Meckling, 1992). Our discussion is directed at a deeper understanding of these characteristics and how they are related to each other and to knowledge transfer costs. The objective is to develop better ways of measuring the concepts and of relating them to firms' decentralization decisions. It is important to understand that these characteristics are not independent. Measures of these characteristics are developed and reported in Section 4.

3.1. Sources of specialized and nonspecialized knowledge

This subsection examines how knowledge is created and what causes knowledge to be more or less specialized. Recall from the discussion in Section 2 that increased specialization of knowledge increases both knowledge transfer costs (by definition) and control costs, because specialized knowledge at lower levels of the firm is not observable by the CEO. All the following characteristics of knowledge, therefore, affect both knowledge transfer costs and control costs.

3.1.1. Ability to automate decision making

Knowledge can be acquired (assembled) in many ways. Partly, knowledge is acquired by experience. When knowledge is assembled through experience, it tends to be specialized. A lathe operator develops knowledge over time about operating characteristics of the machine that are difficult to communicate to others. An arbitrageur develops intuition and judgment that are costly to communicate to someone who does not continually observe financial information, order flow and the evolution of prices. All chemical engineers graduate with similar knowledge. Yet, on the job experience is so important that ten years after graduation chemical engineers in different branches of the chemical industries are unable to perform each other's jobs. Inability to automate the decision making process is the crucial ingredient in these examples that makes the assembled knowledge specialized. If decisions can be automated, then the knowledge on which they are based is nonspecialized.

Automation of decisions requires more than just transmission of data from, say, an arbitrageur to a decision maker. Automation must also capture the skill and judgment the arbitrageur develops over time. Expert systems and neural networks are attempts to automate human skill and judgment that is costly to acquire. Since ability to automate decisions changes with technology, organizational form also changes with technology. On the surface, improvements in computer systems seem to provide the ability to move more knowledge up to decision makers at lower costs. However, a firm's ability to do this is limited by humans' ability to comprehend the transferred data.

3.1.2. Ability to aggregate knowledge

When knowledge can be aggregated, it tends to be nonspecialized. Further, since nonspecialized knowledge can be created by aggregation, it is possible for transfer 'costs' to be negative. There can be a net benefit. For example, it is difficult for the owner of one retail store to determine buying patterns or demand trends. Aggregating across related stores can filter out the noise so that trends can be estimated. There is an information externality among stores. Horizontal integration mitigates this externality problem and enables the assembly of cross-sectional knowledge through aggregation.[9] In a similar fashion, wholesalers learn about demand trends from the orders placed by independent retailers. In contrast to retail chains and wholesalers, which are examples of the assembly of cross-sectional knowledge, boutiques are attempts to capture the value of information about customer-specific preferences. Recent improvements in computer systems, particularly point of sale systems, allow firms to simultaneously aggregate knowledge and take advantage of demand variations by locality.

On the surface, it appears that insurance and financial services firms produce both aggregated (nonspecialized) and specialized knowledge. Insurance companies produce knowledge on average mortality and accident rates; however, they also produce knowledge on the accident rates of particular individuals. However, the knowledge about individuals is easily transferred and so does not meet the definition of specialized knowledge. Further, the essence of insurance is the pooling of risks based on assembled knowledge.

In a similar fashion, financial service companies generate data on individual and average default rates as well as individual deposits and withdrawals. The data on individuals is easily transferred via credit reports and is, therefore, nonspecialized knowledge. Knowledge of aggregate cash flows is valuable in asset management, so knowledge is created via the aggregation and transfer of individual transactions. Transport, communications and utility networks are other instances where there is assembly of knowledge by aggregation; networks are discussed further in Sections 3.1.3 and 3.3.

[9] Aggregation of sales data and later dissemination of the aggregated data could be done by a service agent outside the firm. However, individual stores may be reluctant to release such knowledge to an agent because it helps competitors or entrants and reduces the store's value. Horizontal integration may also reflect scale economies in purchasing and systems development or the value of establishing homogeneity in product quality.

3.1.3. Technology and changes in technology

Technical knowledge is difficult to transmit. One cannot simply hand someone a physics, chemistry, engineering or accounting book and have them be experts in these subjects. Even knowing the theory does not guarantee that someone can apply the knowledge to decisions. A famous example that is similar in spirit to those of the machine operator and arbitrageur is the expert billiards player; see Friedman (1953, p. 22). While the billiard balls obey principles of physics, knowledge of the physical principles is neither necessary nor sufficient to make an expert billiards player.

If a firm has highly technical production processes that are changing rapidly and are fully understood only by people who work with them every day, the further someone rises in the firm the further they are removed from knowledge of the technology. A CEO who rises through the ranks will understand the technology better than a CEO brought in from another industry, but will still know less about the production than experts lower in the hierarchy.[10] At each higher level in the organization, technical knowledge is a subset of that at lower levels. Any firm with technical production processes tends to be of this type. Lathe operators and product design engineers develop knowledge over time that is difficult to convey to others.

For some firms, technology is the primary determinant of organization design. Scale economies in electricity generation, telephone service, gas distribution, cable TV and some transport services make it efficient to have a network; in each case, the product is homogeneous. While, for example, electric generation is highly technical, the distribution system is not. The choice of the electrical generation process (solar, wind, hydro, coal, natural gas or nuclear) affects who runs the power plant. However, specialized knowledge of the generating technology is not required to manage the upper level of the firm. Value maximization mainly requires efficient management of the network (pricing, customer service and maintenance), which does not depend on the generating technology. Marketing, pricing, customer service and maintenance are at the firm level; maintenance is not region-specific.[11] It easy to evaluate managers of billing, maintenance and power plants as cost centers, and pricing decisions occur naturally at the network level. Therefore, when scale economies make it efficient to have a network, we predict firms will centralize; operating units at the first level below the CEO will be cost centers.

Organizational design is not static and evolves through time. Technology is important in understanding what knowledge is specialized and what is nonspecialized (can be easily transferred) at a point in time. Assembly of knowledge by transport networks is one example. When communications are non existent (or poor), knowledge of a particular half-filled tramp steamer and its circumstances (its location, capacity, etc.) is specialized knowledge. The only person who can exploit the knowledge is the captain of the steamer. As communications improve, a firm (or agent) can assemble knowledge on half-filled tramp steamers and goods to be moved to decide whether to delegate someone to take

[10] This is one explanation for most CEOs being internal promotions.

[11] Ice storms, tornadoes and hurricanes all tear down lines; prevention involves cutting back trees in all three cases.

advantage of the knowledge. Changes in technology can both convert specialized to nonspecialized knowledge and lead to assembly of knowledge. Changes in technology can lead to the creation of firms and affect their organization.

3.1.4. Competition

Demand for speed in decision making (immediacy) causes knowledge to be specialized. Immediacy is a function of competition. Machines out of tolerance and arbitrage opportunities are examples where there is value to immediacy; knowledge is valuable only at a particular time and place. Failure to adjust the machine immediately leads to wasted labor and materials and potential damage to the machine. Stopping the machine avoids these costs, but does not avoid loss of output. With competition, failure to act on an arbitrage opportunity immediately leads to loss of the opportunity. Delays in acting on the knowledge destroy (or reduce) its value.

Knowledge can be specialized either by physical transmission delays or from the inability of the decision maker to whom the information is transferred to comprehend and act on the knowledge in a timely manner. Such knowledge is particular to time and place and cannot be aggregated without destroying its value. If prices are unbiased, the average deviation of price from intrinsic value is zero. Sign matters, and averaging destroys information about signs. Similarly, the average deviation of machines from specification is zero.

3.1.5. Demand for product heterogeneity

The degree of specialization of a firm's knowledge depends on demand for product heterogeneity across customers. Product heterogeneity can be induced by geographic dispersion of the firm's operations. Automobiles in different countries need to satisfy different safety and emission regulations, cope with different road and temperature conditions, account for different fuel costs and different skills of mechanics, and perhaps cater to different tastes. Knowledge of local customs, conditions, regulations and preferences is often costly to acquire and costly to transmit to others not familiar with the conditions.

In contrast to products that vary across regions, consider a firm that produces shovels and forks for gardening. There are a limited number of shovel and fork types and most types are used in a wide variety of conditions. While snow shovels are only used in some regions, this knowledge is easily acquired and transferred. Shovel and fork production is not technologically complex.

Automobiles provide an example where a product is tailored to subgroups of customers and the knowledge required to do this is costly to transfer. Shovel and fork production does not require detailed knowledge of individual customers or groups of customers, or that knowledge is easily transferred. Ceteris paribus, one should expect automobile firms to be more decentralized than shovel firms.

3.1.6. Uncertainty

Williamson (1975, p. 24) suggests that the greater the environmental uncertainties, the more likely the decision makers' limited mental and sensory faculties are strained. Hence, the greater the environmental uncertainties, the more specialized is the knowledge. Environmental uncertainty and knowledge transfer costs are likely to be associated with expected and unexpected changes in the environment. The quantity of information increases when the environment is changing rapidly, and delays in acting on information can cause that knowledge to become obsolete. Increased obsolescence rates and increased information flow increase the specialization of knowledge. For this purpose, it does not matter whether the change in the environment comes from the production side (e.g. technological changes) or the demand side (e.g. changes in tastes).

3.1.7. Size

As noted in Section 2, humans have limited storage and processing capacity. Given that the potential amount of knowledge to be transferred to the CEO increases with firm size, the CEO's limited capacity means that the cost of transferring knowledge to the CEO increases with firm size.

3.2. Externalities

If there are operating and information externalities, substitution effects, or complementarities among the components of a business, complete decentralization does not maximize firm value. Maximization of unit profits by each unit manager does not lead to maximization of firm profits. Externalities can take the form of related demand functions (complementarities) or joint supply or cost functions. Quality, learning and reputation are common externalities within firms.

Externalities generate a demand for coordination of the actions of managers of the firm's units. The firm must induce lower level managers to consider the effects of their decisions on other parts of the firm. For example, higher level managers want a business unit manager to consider the effect of the quality of product shipped to another unit on that latter unit's costs. More dependent operations require greater coordination by top management and, hence, lead to larger control costs.

Two other sources of externalities are reputation and product and other tortious liabilities. There are reputation externalities among the divisions of a firm. University administrations (CEOs) delegate decisions about research, course content and hiring untenured faculty to schools and departments, but to protect the university's reputation, retain a right of veto over promotion and tenure. Personnel functions are often consolidated at the corporate level to control liabilities associated with anti-discrimination laws. Product testing is often reviewed by corporate legal departments prior to new product introductions.

There are three possible solutions to externalities within a firm. First, performance evaluation and compensation of the managers of operating units can depend on the joint outcomes of multiple units. Second, the cost allocation and transfer pricing systems can impose taxes and/or subsidies. Third, in the absence of knowledge transfer costs, the coordination problem can be solved by centralization. Focusing on the latter solution, we expect that firms with more externalities among their operations are more centralized. Conversely, the less managers' actions affect the results of other operating units, the more decentralized we expect the firm to be.

3.3. Regulation

Price regulation can affect decentralization. Price regulation is primarily at the firm level, which encourages the firm to transfer knowledge to top management for regulatory purposes. This reduces the cost of transferring knowledge for other purposes, encourages regulated firms to centralize, and reinforces our prediction in Section 3.1.3 that firms with networks will centralize.[12] However, we argue in Section 3.1.3 that when scale economies make it optimal to have a network, decision rights are centralized, and the network is the natural profit center. The dependent variable we use as a proxy for decision right allocations is use of profit centers at the second level. It is unlikely that this measure allows us to detect any incremental effect of price regulation on decision right allocations.

There are two other difficulties with treating regulation as an independent influence on decentralization. First, regulation is applied to natural monopolies and so may be endogenous. If monopolies tend to centralize to capture the benefits of monopoly, then regulation stems from the same factors causing centralization and should not be included as an exogenous variable affecting decentralization.

Second, regulation can act as a proxy for other factors that determine decentralization of decision rights, specialized knowledge and externalities. Regulated industries tend to involve networks, where there are gains from the aggregation of knowledge. Hence, regulation serves as a proxy for low knowledge transfer costs and is likely to be associated with less decentralization. Also, regulatory bodies restrict top management's discretion, including discretion over the type of investments managers can make. This tends to reduce growth, uncertainty and the variance of regulated firms' cash flows (Smith and Watts, 1992). This effect is reinforced by utilities' monopoly position. Utilities do not face uncertainty created by the actions of direct competitors. Consequently, regulation is negatively related to growth and uncertainty and is likely to be associated with less decentralization.

Finally, to the extent that regulators restrict firms to one industry, regulation also is positively related to externalities and again is likely to be associated with less decentralization. Regulation, therefore, acts as a proxy for three other factors associated with less decentralization. All three proxy relations suggest regulation is negatively associated with decentralization. These proxy relations do not imply regulation, per se, affects decentralization.

3.4. Summary of relations among decentralization and IOS characteristics

The discussion in Sections 2 and 3 is summarized as follows. Decentralization is implicitly a function of knowledge transfer costs (KTC), control costs (CC) and price regulation (REG). Control costs depend on KTC and externalities (EXT), see Eq. (1).

[12] This argument applies to price regulation. The knowledge required to meet other regulations, such as health and safety, is often specialized and at low levels of the firm. In such cases, regulation can cause decentralization of some decision rights.

Decentralization increases with KTC and decreases with CC and REG; CC increase with KTC and EXT. Since KTC and CC are unobservable, we estimate a reduced form. We address this issue in Section 5.

4. Measurement of IOS characteristics and descriptive statistics

This section develops measures of the IOS characteristics discussed in the prior section (in the same order) and provides related descriptive statistics. The questionnaire provides evidence on the organization of the firm at the second level. It elicits data on profit and cost centers, externalities among firms' investments and firm size. We end up with a sample of 121 CRSP/Compustat firms. The questionnaire, details of the sampling procedure and a summary of the results are available by request. In relation to the set of Compustat firms, we obtain a representative size sample. The only bias of consequence is that utilities, financial and insurance companies are over represented. Since much of the cross-sectional variation in growth and risk stems from the regulated firms, this increases statistical significance somewhat compared with a random sample. However, even when all regulated firms are excluded the tenor of our results is unchanged.

Panels A and B of Table 1 provide the distributions of the variables used for the 121 firm sample. For descriptive purposes, we report raw correlations in Appendix A. We make only passing reference to these correlations, since the theory is about partial, not total, effects.

4.1. Measures of specialized knowledge

As we discuss in Section 3, there are multiple related IOS characteristics that cause knowledge to be specialized. We provide five measures that jointly attempt to capture that discussion. Three of these measures (growth, uncertainty and size) are objective and two rely on an ex ante classification of SIC codes. We call the latter two variables average knowledge specialization ($\overline{\mathrm{KS}}$) and incremental knowledge specialization (ΔKS). They are intended to capture aspects of variation in knowledge generation across firms not captured by growth and uncertainty.

Mendelson and Pillai (1999) use survey data to investigate 'clockspeed' in the electronics industry. Clockspeed captures both supply side technology changes and changes in demand, some of which are caused by the technological changes. Clockspeed is related to several of the sources of specialized knowledge we discuss in Section 3.1: technology, changes in technology, competition and uncertainty. Mendelson (2000) relates clockspeed and other measures to organization design. While we cannot use clockspeed directly, Mendelson and Pillai find that the correlation of their clockspeed measure with uncertainty, which we do use, is about 0.8. We also expect that across industries, clockspeed is positively correlated with our ($\overline{\mathrm{KS}}$) and (ΔKS) measures.

We report regressions both with and without the variables that use the ex ante SIC classifications. Inclusion of ($\overline{\mathrm{KS}}$) and (ΔKS) as explanatory variables produces well-specified regressions that suggest the variables capture attributes of specialized knowledge not incorporated in growth, uncertainty or size. However, vindication of the industry classification scheme's relation to specialized knowledge relies on verification of this relation in other contexts and samples.

4.1.1. Average knowledge specialization

Our first measure of knowledge specialization is designed to capture the average degree of specialization of knowledge at 'low' levels of the firm. Low means anywhere below the second level. We call this measure average knowledge specialization ($\overline{\mathrm{KS}}$).

There are two steps in determining $\overline{\mathrm{KS}}$. First, we classify major categories of SIC codes by whether they tend to generate relatively more specialized or nonspecialized knowledge. These classifications are based on the analysis in Section 3.1 and are provided in Table 2. Industries classified as generating relatively more specialized knowledge are coded as having knowledge specialization one, those classified as generating relatively more nonspecialized knowledge are coded as zero and those coded as producing mixed nonspecialized and specialized knowledge are coded one-half.

Second, $\overline{\mathrm{KS}}$ for each firm is calculated as the average degree of specialization of knowledge for all four-digit industries in which the firm operates. All the four-digit industries in which each of the sample firms is engaged are obtained from Standard and Poor's Register and Dun's Million Dollar Directory.

The number of lines of business (SIC codes) owned by our sample firms (NLOB) ranges from 1 to 38 with a mean of 8. So that all our variables and coefficients are approximately on the same scale, we divide NLOB for each firm by MAXLOB, the maximum NLOB in our sample of 38. This scaling has no effect on t statistics or their associated probabilities, and facilitates calculation of ΔKS (see Section 4.1.2). The coefficients and standard errors are simply scaled by the same proportion. The mean of the standardized number of lines of business (SNLOB) is 0.21, with a range from 0.03 to 1.0.

Table 2
Classification of industries by knowledge specialization

Group number	SIC codes	Industry	Knowledge specialization	Code
1	0100–0999	Agriculture, Forestry and Fishing	Specialized	1.0
2	1000–1499	Mining	Specialized	1.0
3	1500–1599	Construction: General Building	Mixed	0.5
4	1600–1699	Construction: Heavy	Specialized	1.0
5	1700–1799	Construction: Special Trade	Mixed	0.5
6	1800–1999	Unused		
7	2000–3999	Manufacturing	Specialized	1.0
8	4000–4999	Transportation and Public Utilities	Nonspecialized	0.0
9	5000–5199	Wholesale Trade	Nonspecialized	0.0
10	5200–5999	Retail trade	Nonspecialized	0.0
11	6000–6199	Finance	Nonspecialized	0.0
12	6200–6299	Security and Commodity Brokers	Mixed	0.5
13	6300–6999	Insurance and Real Estate	Nonspecialized	0.0
14	7000–8999	Services	Mixed	0.5
15	9000–9999	Government and Public Administration	Mixed	0.5

We argue in the previous section that retail chains and wholesalers learn about demand trends from assembling data and that such data are nonspecialized. While it is possible for a salesperson to generate specialized knowledge about a customer's preferences, this is more likely in 'boutique' operations where there is a high incidence of salesperson-specific repeat business. This is less likely with retail chains, which are the type of retail firms in our sample. Exploitation of customer-specific knowledge is a likely explanation for the existence of boutiques. Wholesale firms supplying retail firms can also assemble knowledge on demand trends. We also argue that insurance and financial firms produce primarily nonspecialized knowledge at low levels in the firm. Therefore, we classify retail, wholesale, insurance and finance firms as producing primarily nonspecialized knowledge.

In Section 3.1, we also argue that with modern communications, firms characterized by networks produce knowledge that is easily transferred and the firms gain from the aggregation and assembly of knowledge. Hence, we classify transport, communications and utility firms as producing relatively less specialized and relatively more nonspecialized knowledge.

We expect firms with physical production processes, such as those in manufacturing, agriculture, mining and construction, to generate relatively more specialized knowledge. There is less gain from assembly of knowledge in these industries relative to the technical knowledge that is costly to transfer. Melumad et al. (1992) make a similar argument. We also expect these industries to have relatively more product heterogeneity and decisions that are harder to automate. Therefore, with two exceptions, we classify all primary production (agriculture, forestry, fishing and mining), construction and manufacturing industries as producing relatively more specialized knowledge. The exceptions are industries related to residential home construction. Large-scale builders of homes (general building contractors in Table 2) probably gain some assembled knowledge about consumer demand and so we classify that industry as mixed. The 'Construction: Special trade' industry in Table 2 is involved in some residential home construction and so is also classified as mixed.

Compared with other industry groupings, there is a great deal of variation within the service industries (SIC codes 7000 through 8999) that precludes categorizing the broad group as producing primarily specialized or nonspecialized knowledge and so those industries are classified as mixed. Security and commodity brokers can produce both nonspecialized and specialized knowledge (arbitrage opportunities) and so are also classified as mixed.

Of the 121 firms, 42 have an average knowledge specialization of 0.0 (nonspecialized) and 22 have $\overline{\mathrm{KS}}$ of 1.0 (all specialized). The mean knowledge specialization is 0.49 and the median is 0.60 (see Table 1, panel B).

4.1.2. Specialized knowledge at the second level

When the skills needed to run a particular business are costly to transmit, then firms that own more than one business will effectively produce specialized knowledge at the second level. It is an empirical matter whether the degree of specialization of the knowledge produced within each of a firm's lines of business or the specialized knowledge needed to run given lines of business dominates organizational design at the second level.

For example, consider an insurance firm that writes say automobile, product liability, marine and general casualty, and life insurance. We argue that each of these insurance businesses generates primarily nonspecialized knowledge, yet the knowledge required to manage each of these lines of business may be highly specialized.

Our knowledge specialization variable ($\overline{\mathrm{KS}}$) reflects the average degree of specialization over all of a firm's lines of business. We also have to measure the incremental effect on a firm's knowledge specialization of knowledge required to run each line of business. We expect that this incremental effect increases with the number of lines of business the firm owns, and is largest for firms that produce primarily nonspecialized knowledge within each line of business.

We define $\Delta\mathrm{KS}$ as $\mathrm{SNLOB}(1-\overline{\mathrm{KS}})$, where the $\Delta\mathrm{KS}$ indicates that this effect is incremental. $\Delta\mathrm{KS}$ is increasing in the number of lines of business a firm has and is largest when the firm generates primarily nonspecialized knowledge within each line of business. $\Delta\mathrm{KS}$ measures the incremental effect of specialized knowledge required to run each line of business within a firm. $\overline{\mathrm{KS}}$ is between zero and one, and SNLOB is scaled to be between zero and one, $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ are on a similar scale. As reported in Table 1, panel B, $\Delta\mathrm{KS}$ ranges from zero to 0.55 with a mean of 0.07. It is increasing in the number of lines of business and has a larger partial effect for firms that produce primarily nonspecialized information within each line of business.

4.1.3. Growth options

Growth options are one manifestation of environmental change. In mature firms with few growth opportunities, demand and cost functions are likely to be well known and stable. Knowledge of those functions can be transferred to top management at relatively low cost. In growth firms, however, information on demand conditions and costs is likely to be arriving more frequently (e.g. as new investments are made and as the demand for the new product is revealed) and be more time-specific. If knowledge of the opportunities presented by growth options resides at the second level or lower in the organization, the existence of growth options (i.e. opportunities to invest at above the competitive rate of return) causes knowledge to be more specialized.

We measure growth (GROW) as the ratio of the market value of equity plus the book value of debt to the book value of total assets using data obtained from Compustat and CRSP. Variants of this variable have been used to represent growth options in empirical studies of the relation between firms' investment opportunity sets and corporate financial, dividend and compensation policies (e.g., Smith and Watts, 1992; Gaver and Gaver, 1993). Those studies tend to find a relation between GROW and corporate policies. In our sample, the mean of GROW is 1.26 and the median is 1.09. The range is 0.72 to 3.08.

4.1.4. Uncertainty

Changing conditions in the firm's product and input markets affect the volatility of cash flows and this, in turn, is reflected in the volatility of the rate of return. Ideally, we would like to observe the standard deviations (volatilities) of individual divisions, since it is these volatilities that affect whether knowledge can be transferred to the CEO from the second level managers. The volatility of the rate of return on the firm reflects diversification across lines of business. Ceteris paribus, more lines of business (divisions) implies lower volatility. While firm volatility is an increasing function of divisional volatilities, it is a decreasing function of the number of divisions. We, therefore, generate our uncertainty measure in two steps.

First, we estimate the volatility (UNC) of the firm's rate of return on equity over the sixty months up to and including December 1987.[13] Second, to capture the uncertainty at the divisional level we adjust UNC by the correlations among the firm's lines of business. We call this variable DUNC for divisional uncertainty, and use it as the uncertainty variable in our regressions.

The conversion from UNC to DUNC is to divide by the square root of $\{1/\mathrm{NLOB}+[(\mathrm{NLOB}-1)/\mathrm{NLOB}]\times \mathrm{CORR}\}$, where NLOB is the number of lines of business (industries) the firm is in, and CORR is the average off diagonal correlation among the firm's lines of business.[14] We generate these correlations using industry indices at both the two- and three-digit SIC level. Our results are not sensitive to the SIC level at which we make this adjustment.

Sixty months of data are available to estimate UNC for 114 of the 121 firms. The mean number of months over which the standard deviation is estimated for the other seven firms is 35 and the minimum number of months used in the estimation is 21. In Table 1, the mean DUNC is 0.32 and the median is 0.31. The maximum is 0.72 with a minimum of 0.15. While these numbers differ only slightly from the corresponding UNC numbers in Table 1, from Appendix A, one can see that the correlation of DUNC with other variables is greater than that of UNC for all except GROW, SIZE and REG.

4.1.5. Size

The only size variable reported is annual sales, since the results are not sensitive to the alternative size measures that are used. The sales data are obtained from Compustat.[15] As with SNLOB, the sales numbers obtained from Compustat are scaled by the maximum of the cross-sectional distribution of sales. The sales data indicate that our 121 firm sample consists of large firms. However, as noted above, the size of firms in the sample is not significantly different from the size of Compustat firms that did not respond to the questionnaire. The mean size variable is 0.06 with a median of 0.02.

There is considerable size variation in the sample; however, this may not be sufficient if there is a threshold effect with size. If size per se leads to decentralization of decision rights only after the firm reaches a given size, and if most of our firms are larger than this threshold, then continuous measures of size will not capture the important effect of size on decentralization. The evidence in Section 5 is consistent with this conjecture. This also

[13] Ideally, we would unlever the equity volatility to calculate the underlying variance of the rate of return on the firm. Christie (1982, 2000) finds that the adjustment to unlever risky debt varies with leverage and that most of the cross-sectional variation in equity return variance is due to variation in firm return variance. This suggests that using the unlevered variance instead of the equity return variance may increase measurement error, rather than reduce it.

[14] This adjustment arises because the firm is a portfolio of its component divisions. Volatility of the firm's returns is a function of the average volatility of divisional returns and correlation among the divisions.

[15] We also use number of employees. Both categorical variables from the questionnaire and continuous variables from Compustat are used. With one minor exception, the two data sources are consistent.

suggests that a dummy variable related to the threshold would be a better size measure than the continuous and categorical variables we use.

4.2. Measurement of externalities

Externalities are always difficult to quantify, although typically it is easy to determine the sign. While our analysis only requires determining the existence of externalities, as outsiders this is not trivial. Therefore, we use multiple measures of externalities. First, there is disagreement in the literature about what the externalities variable obtained from the questionnaire measures. Second, we have additional reservations about the measure. Third, alternative measures provide evidence about the robustness of our results. Finally, the primary externalities measure is the only explanatory variable obtained from the questionnaire. A measure of externalities from publicly available sources, combined with finding an objective way of measuring decentralization from public sources, would permit much larger data sets, both cross-sectional and time series.

4.2.1. A measure of externalities obtained from firms

The primary externalities variable (EXT) is obtained from answers to a question developed by Rumelt (1974) and used by Vancil (1978). We ask respondents to classify their firm as being a single business, having a dominant business, having related businesses or having unrelated businesses. The first classification (single business) suggests significant externalities and is coded four and the last classification (unrelated businesses) suggests few externalities and is coded one. Dominant business and related businesses are coded three and two, respectively.[16]

Vancil (1978, pp. 7–8) treats our externalities variable as a measure of knowledge transfer costs, not externalities. He expects CEOs in firms with investments in diverse products to lack the expertise to make detailed decisions for those units. CEOs of firms whose investments are not very diverse are more likely to have that expertise and so are more likely to make those unit decisions. Implicit in this argument is the assumption that the expertise is costly to transfer, otherwise the current difference in expertise would not matter. Based on this implicit specialized knowledge argument, Vancil predicts (as we do) that decentralization decreases as EXT increases. While Vancil's prediction holds only if specialized knowledge has a larger effect on knowledge transfer costs than on control costs, the evidence we present below is consistent with such a conjecture.

The externalities question is intended to capture the existence of production and information externalities within the firm. A potentially greater concern than whether EXT partially measures knowledge transfer costs is that the externalities question may do nothing more than ask the reverse of the decentralization question. That is, asking whether the firm has related or unrelated businesses might simply be the converse of asking whether it is decentralized.

[16] The dependent variable (DEC) focuses on line units and so excludes corporate finance, treasury, personnel and legal functions. Therefore, we do not need to include cross-sectional differences in tort exposure in the measure of externalities. Later, we discuss and develop a measure of externalities that is independent of the questionnaire.

The distribution of answers to the externalities question in Table 1 is 21% for unrelated businesses, 27% for related businesses, 23% for a dominant business and 29% for a single business. This distribution is similar to the distribution reported by Vancil (1978, p. 154), which is 30%, 28%, 22% and 20%, respectively. We have a few more firms in the single business category and a few less in the unrelated category than Vancil. This is probably due to the over representation of utilities and banks in our sample. We create dummy variables (EXT2, EXT3 and EXT4) for the last three externalities categories, which are in order of increasing externalities.

4.2.2. Alternative measures of externalities

We next define an externalities measure that can be obtained from publicly available data. Define EXTLOB as one if all the firm's lines of business fall within a single two-digit SIC group, and zero otherwise. This is intended to capture the spirit of EXT4 that the firm is a single business. The means of EXT4 and EXTLOB are essentially identical at 0.29 and 0.30 and have a correlation of 0.46. In relation to EXT4, EXTLOB is more highly correlated with both REG (0.46 vs. 0.34) and SNLOB (-0.51 vs. -0.44). EXT4 and EXTLOB are related but not identical measures. One potential reason they are not perfectly correlated is that we assign equal weights to all the firm's lines of business. In contrast, we presume that firms give more important lines of business greater weight when answering the questionnaire.[17]

Baiman et al. (1995) analyze the relation between task allocation to business units at the second level, units' proportion of total firm sales, and a measure very similar to EXTLOB. The task allocation variable is coded one if the business unit has direct control over its core function, and zero otherwise. The task allocation variable is obtained from a consulting firm's questionnaire, and is a measure of decentralization. The EXTLOB-like measure is meant to measure the CEO's expertise (knowledge), and is coded one if the business unit's two-digit SIC code is the same as the corporation's, and zero otherwise. One reason for high CEO' expertise is low knowledge transfer costs. The *z*-statistic for their expertise variable's *t*-statistics in eight individual industry cross-sectional regressions is -2.31, which is significant at the 0.05 level. That is, Baiman, Larcker and Rajan obtain a negative relation between decentralization and an EXTLOB-like variable; their interpretation is similar to Vancil's.

Vancil (1978) and Baiman et al. (1995) interpret each of our externalities measures as measures of specialized knowledge. Ultimately, what these variables are measuring is an empirical issue. We include several measures of specialized knowledge ($\overline{\mathrm{KS}}$, ΔKS, GROW, DUNC and SIZE). Since least squares orthogonalizes all explanatory variables against each of the others, at the very least, estimated coefficients on our externalities variables will reflect only effects that are uncorrelated with our measures of specialized knowledge. That is, our regressions provide the opportunity to disentangle these measurement issues.

[17] It is, superficially, possible to use the Compustat segment files to weight SIC codes. However, the FASB's segment reporting rules need have little to do with lines of business, notwithstanding Compustat assigns SIC codes to the reported segments. A segment can be a region or a major customer.

4.3. Measurement of regulation

REG is defined on an industry basis depending on the primary industry listed for a firm in Dun's Million Dollar Directory. If the primary industry is utility, transportation or communications, the firm is defined as being regulated and its regulatory variable is coded as one. All other firms have their REG variable coded as zero. As we argue in Section 3.3, REG is negatively correlated with growth and uncertainty and positively correlated with externalities.

The sample includes 28 firms whose primary industry classification is in the utility, communications, transportation or railroads industries, so the mean regulation variable in Table 2 is 0.23 and the median is zero. Most regulated firms are utilities (24). Two firms are in the communications industry, one is a railroad and one is a trucking firm.

From the correlation matrix in Appendix A, REG is significantly correlated with the dependent variable (DEC) and most of the independent variables ($\overline{\mathrm{KS}}$, ΔKS, GROW, DUNC and EXT). Therefore, we estimate the model both with and without a regulation variable. We also check whether the association between the factors (other than regulation) is driven by regulated industries, by estimating the model excluding firms in regulated industries.

4.4. Summary of expected empirical relations

We can summarize the predicted empirical relations with the following equation:

$$\begin{aligned}\mathrm{DEC} = {} & \alpha_0 + \alpha_1 \overline{\mathrm{KS}} + \alpha_2 \Delta\mathrm{KS} + \alpha_3 \mathrm{GROW} + \alpha_4 \mathrm{DUNC} + \alpha_5 \mathrm{SIZE} \\ & + \alpha_6 \mathrm{EXT} + \alpha_7 \mathrm{REG}.\end{aligned} \tag{2}$$

The dependent variable is the extent of decentralization of decision rights to the firm's second management level (DEC). The proxy for DEC is a firm's relative use of profit and cost centers one level below the CEO; these data are obtained from a questionnaire. The predetermined variables are the firm's average knowledge specialization ($\overline{\mathrm{KS}}$) and incremental (second level) knowledge specialization (ΔKS), growth options (GROW), average uncertainty of the firm's investments at the divisional level (DUNC), firm size (SIZE), externalities among the firm's investments (EXT) and whether the firm is regulated (REG). One proxy for EXT is obtained from the questionnaire. Data for GROW, DUNC, REG and alternative measures of EXT are obtained from CRSP, Compustat, Dun's Million Dollar Directory, and the Standard and Poor's Register.

Eq. (2) forms the basis for our empirical work predicting the extent of decentralization. We expect α_6 and α_7 to be negative. Increasing externalities increase control costs and lead to less decentralization. Price regulation leads to transfer of knowledge upwards for regulatory purposes and thereby lowers the cost of centralization.

We predict that α_1, α_2, α_3, α_4 and α_5 are non zero, but should all have the same sign. The signs of these five coefficients depend on the relative effects of knowledge transfer costs and control costs on decentralization. Recall Eq. (1). If, on average, the direct effect of

KTC on decentralization is large relative to the indirect effect through the control costs, the coefficients of $\overline{\mathrm{KS}}$, ΔKS, GROW, DUNC and SIZE are positive.[18] If the converse is true, all five coefficients are negative. So α_1, α_2, α_3, α_4 and α_5 are expected to have the same sign. As discussed in Section 4.2, we also expect the inclusion of the knowledge specialization variables ($\overline{\mathrm{KS}}$ and ΔKS) to reduce the coefficients on the other specialized knowledge variables and on EXT.

5. Empirical relation between decentralization and IOS characteristics

Eq. (2) is a reduced form and is potentially subject to simultaneous equation bias. It also includes mismeasured variables and potentially excludes correlated explanatory variables. While knowledge transfer cost and control cost functions for some firms may be nonlinear, this does not imply that the cross-sectional empirical relation between decentralization choices for firms and the explanatory variables is nonlinear. We estimate Eq. (2) using linear least squares and test for misspecifications including nonlinearities.

In Section 4, we discuss measurement of specialized knowledge and externalities, the possibility that our externalities measures also capture specialized knowledge, and develop measures of specialized knowledge that depend on our ex ante classification of SIC codes ($\overline{\mathrm{KS}}$ and ΔKS). To provide assurance that our classifications are not driving all our results, we estimate regressions both without $\overline{\mathrm{KS}}$ and ΔKS (Section 5.1) and with them (Section 5.2). Further, we predict that including $\overline{\mathrm{KS}}$ and ΔKS reduces the coefficients on the externalities measures if the EXT measures are partially capturing specialized knowledge.

The decentralization (dependent) variable in Eq. (2) is discrete. Firms either have all profit centers, mixtures of profit and cost centers, or all cost centers. This suggests Eq. (2) should be estimated using Logit or Probit analysis. However, Noreen (1988) finds that while tests of individual coefficients are well specified using both Probit and ordinary least squares in empirical studies of this nature with this sized sample, Probit's chi-square test of fit rejects the null too frequently. Ordinary least squares' F-test, on the other hand, is reasonably well specified. Stone and Rasp (1991) report similar results for Logit. Hence, we employ ordinary least squares. Least squares also has the advantage that it is easy to generate specification and collinearity diagnostics and to test for nonlinearities.

To address potential econometric problems (endogenous variables, errors in variables, correlated omitted variables and non-linearity), two diagnostics are used in all the regressions. The first is a specification test due to White (1980) that can reject if either the regression errors are heteroscedastic or if the errors and explanatory variables are dependent. Since the latter case covers errors in variables, correlated omitted variables,

[18] A prediction to this effect is in Chandler (1962).

simultaneities and nonlinearities with respect to explanatory variables, this is a general test of specification.[19]

The second diagnostic reported is a test for nonlinearities due to Christie (2000). The residuals are sorted by the values of continuous explanatory variables and a Durbin–Watson statistic is calculated for each continuous variable. Nonlinearities are reflected in positively autocorrelated errors. It is assumed that except for the influence of nonlinearities, the regression errors are cross-sectionally independent.[20] There is no evidence of nonlinearity.

Reported probabilities of test statistics are for one-tail tests when we predict the sign of an association and two-tail otherwise. All significance levels of 0.0001 should be interpreted as less than or equal to 0.0001. All reported results use the two-digit SIC level to adjust UNC for intra-firm correlations to obtain DUNC, since the results are not sensitive to whether we do this at the two or three-digit level.

5.1. Empirical results excluding SIC-based knowledge specialization variables

We first estimate our regressions excluding the two knowledge specialization variables that rely on our ex ante classification of SIC codes ($\overline{\mathrm{KS}}$ and ΔKS). This provides assurance that our classifications are not driving all our results and provides a benchmark to assess the contribution of $\overline{\mathrm{KS}}$ and to understanding the decentralization decision.

Section 3.3 expresses reservations about the exogeneity of the regulation variable and discusses the problem that regulation can proxy for IOS characteristics that cause decentralization. From Appendix A, REG is highly correlated with the dependent variable and most of the independent variables. Therefore, we first estimate Eq. (2) without the regulated firms. Column (1) in Table 3 contains the results from that estimation. As we predict, the estimated coefficients on the specialized knowledge variables (GROW, DUNC and SIZE) in column (1) are of the same sign (positive); however, only GROW is significant at the 0.10 level. The positive sign is consistent with knowledge transfer costs being relatively more important to organization design than control costs, consistent with the predictions of Chandler (1962).

Each of the externalities dummies has the predicted negative sign with probabilities of 0.23, 0.09 and 0.0004. As expected, the coefficients on the externalities dummies EXT2 (related business), EXT3 (dominant business) and EXT4 (single business) are monotonically decreasing. They approximately double from one category to the next in order of increasing externalities. The three coefficients are -0.06, -0.12 and -0.31. We show below that the negative coefficient on EXT2 is robust to different specifications, notwithstanding it is not usually statistically significant.

[19] White also provides a variance/covariance matrix of the coefficient estimators that converges to the true variance/covariance matrix in large samples, if the model is well specified. This allows calculation of test statistics that are unbiased, but inefficient, if the White test is detecting heteroscedasticity rather than misspecification. We discuss this further in Section 5.3.

[20] The Belsley et al. (1980) collinearity diagnostics are calculated for all regressions. It is evident from Appendix A that our independent variables are collinear, but there is no evidence that collinearity is degrading the estimators.

The regression itself is significant at less than the 0.004 level and the adjusted R^2 is 0.14. The Durbin–Watson statistics indicate there are no nonlinearities with respect to the continuous variables (SIZE, GROW and DUNC).

Excluding regulated firms provides a regression that is inefficient, since much of the cross-sectional variation in explanatory variables is associated with regulated firms. When the regulated firms are included in the regression (column 2), the absolute value and significance of the coefficients of all the independent variables increases as does the adjusted R^2 (from 0.14 to 0.39). The most noticeable changes are that the coefficients on GROW and DUNC at least double and both become much more significant (GROW from 0.073 to 0.0021 and DUNC from 0.30 to 0.0001). The coefficients on the EXT dummies are still monotonic, and roughly maintain their relative magnitudes.

When REG is included in the estimation of Eq. (2) (column 3), the absolute value and significance of all the other independent variables except EXT2 drops. However, DUNC (which was insignificant in the unregulated firm regression in column (1)) remains significant at the 0.08 level. REG itself is negative (as predicted) and significant at the 0.0002 level. The EXT dummies maintain their monotonicity and the coefficient of EXT4 is still three times the magnitude of EXT3. The adjusted R^2 increases from 0.39 to 0.45. The Durbin–Watson statistics indicate no nonlinearity.

If GROW, DUNC and the EXT dummies are measured without error, the significant coefficient on REG indicates that regulation has marginal explanatory power for decentralization. However, we argue in Section 3.3 that REG acts as a proxy for the underlying concepts we are trying to capture with these other variables. It is, therefore, possible that REG has no marginal explanatory power, notwithstanding its significant negative coefficient. We have no way to distinguish these possibilities with available data. However, the level of significance of the coefficients on GROW, DUNC and the EXT dummies in column (1) indicate that REG is not driving all the results.

In each of the first three columns of Table 3, we report an F-test on the hypothesis that the coefficients on the three EXT dummies are equal; in each case we reject this hypothesis at the 0.01 level or better. From columns (1)–(3), the coefficient on EXT4 is approximately two to three times that on EXT3, four to five times that on EXT2 and by far the most statistically significant. This suggests that externalities are most important when the firm considers itself a single business. Therefore, we next include EXT4 as the only externalities measure in the regression. Our externalities measure is one if the firm is a single business and is zero otherwise. This regression, which we report in column (4) of Table 3, also includes GROW, DUNC, SIZE and REG. The t-statistic on EXT4 is -4.34. The coefficients and t-statistics on the other variables are similar to those in the corresponding column (3), as are the adjusted R^2, F-statistic and Durbin–Watson statistic. At least with this sample, the results are robust to dropping EXT2 and EXT3.

The results of using EXTLOB as the externalities measure are reported in column (5) of Table 3. The coefficient on EXTLOB has a t-statistic of -5.01. The results for the other coefficients are similar to column (4). All the coefficients have the same signs and approximately the same significance levels except for DUNC, for which the significance drops from 0.07 to 0.16.

The analysis is repeated using EXTLOB calculated at the three-digit level (not reported). That is, EXTLOB3 is one if all the firm's SIC codes are within a single

Table 3
Determinants of decentralization excluding knowledge specialization: dependent variable DEC

	Predicted sign	Unregulated firms (1)	All firms (2)	All firms (3)	All firms (4)	All firms (5)	All firms[a] (6)
Sample size in 1987[b]		93	121	121	121	121	121
Intercept	?	0.61	0.16	0.51	0.42	0.49	0.55
t		3.43	1.06	2.92	2.57	3.00	2.66
Prob. (t)		0.0009	0.29	0.004	0.012	0.003	0.009
GROW	?	0.11	0.21	0.14	0.15	0.15	0.10
t		1.82	3.15	2.15	2.41	2.35	1.45
Prob. (t)		0.073	0.0021	0.034	0.018	0.02	0.15
DUNC	?	0.35	1.23	0.58	0.59	0.46	0.42
t		1.05	4.27	1.77	1.80	1.42	1.31
Prob. (t)		0.30	0.0001	0.079	0.074	0.16	0.192
SIZE	?	0.32	0.43	0.31	0.25	0.23	0.19
t		1.48	1.92	1.43	1.21	1.11	0.95
Prob. (t)		0.143	0.058	0.155	0.23	0.27	0.34
EXT2	–	– 0.06	– 0.09	– 0.09			
t		– 0.73	– 1.05	– 1.11			
Prob. (t)		0.23	0.15	0.14			
EXT3	–	– 0.12	– 0.15	– 0.12			
t		– 1.34	– 1.63	– 1.42			
Prob. (t)		0.09	0.053	0.08			

EXT4	–	– 0.31	– 0.42	– 0.36	– 0.30		
t		– 3.48	– 4.92	– 4.29	– 4.34		
Prob. (*t*)		0.0004	0.0001	0.0001	0.0001		
EXTLOB	–					– 0.34	– 0.32
t						– 5.01	– 4.23
Prob. (*t*)						0.0001	0.0001
REG	–			– 0.31	– 0.31	– 0.27	– 0.29
t				– 3.63	– 3.74	– 3.24	– 2.17
Prob. (*t*)				0.0002	0.0003	0.002	0.016
Adjusted R^2		0.14	0.39	0.45	0.45	0.48	0.50
Prob. *F* (All coefficients = 0)		0.0034	0.0001	0.0001	0.0001	0.0001	0.0001
Durbin – Watson (SIZE)[c]		2.16	2.06	2.13	2.14	1.99	2.14
Prob. (White statistic)		0.14	0.037	0.052	0.20	0.25	0.72
Prob. *F* (EXT2 = EXT3 = EXT4)		0.01	0.0001	0.0013			
Prob. *F*[d] (All theory variables = 0)							0.0001
Prob. *F* (All Industry Dummies = 0)							0.117

[a] Coefficients and *t*-statistics on eight industry dummies are not reported.

[b] DEC = Decentralization. Equals one if the second level units are all profit centers, zero if they are all cost centers, and one-half if there are both profit and cost centers. GROW = Growth measured by the ratio of market value-to-book value of the firm. NLOB = Number of lines of business (four-digit SIC codes) the firm operates in. UNC = Std. dev. of rate of return on equity for the 60 months ended December 1987. DUNC = UNC/SQRT{1/NLOB+[(NLOB − 1)/NLOB] × CORR}. CORR = Average off diagonal correlation among the firm's lines of business at the two-digit SIC level. SIZE = Sales for 1987 as per Compustat. EXTi = Externalities among business units. EXT2, EXT3 and EXT4 are coded one for related businesses, dominant business and single business, and zero otherwise. EXTLOB = Coded one if all the firm's SIC codes are in the same two-digit group, zero otherwise. REG = Unity if the firm's primary industry is utility, transportation or communications.

[c] The Durbin-Watson statistic with the residuals sorted by size. This is a test for nonlinearity. The Durbin-Watson when the residuals are sorted by the uncertainty variable is similar to those reported by size.

[d] Theory variables are GROW, DUNC, EXTLOB, SIZE, and REG.

three-digit group, and zero otherwise. This variable has a lower correlation with EXT4 than does the corresponding two-digit version (0.36 vs. 0.46). Further, although EXTLOB3 has a negative sign when only unregulated firms are included, it is less significant than both EXT4 and EXTLOB. The coefficient on EXTLOB3 is not significantly different from zero when all firms are included. We attribute these differences to the fact that this stronger criterion for externalities is more sensitive to our equal weighting of all the firm's SIC codes. That is, a firm could have operations in two different three-digit SIC codes within the same two-digit classification; however, one could be a relatively unimportant part of the firm's operations. EXTLOB3 would classify such a firm as having no externalities, when in fact most of its operations are within the same three-digit code and closely related. Since firms' disclosures of segment data in annual reports bear no necessary relation to SIC codes, we have no way to weight firms' SIC codes and, hence, no way to test these conjectures.

We draw two conclusions from Table 3, columns (4) and (5). First, our results are robust to different ways of measuring externalities. Second, it is possible to derive a reasonable alternative measure of externalities from publicly available data, notwithstanding that measure equally weights the firm's SIC codes.

Overall, the relation of decentralization with knowledge transfer costs and externalities is robust. While the various specifications estimated are not independent, the signs of the coefficients are always the same, consistent with our predictions, and invariant to the particular model. Even without the regulated firms, there is a significant relation between IOS characteristics and decentralization. These statements must be tempered by the knowledge that our regressions are potentially misspecified. Within the limits of the data, we discuss this further in later subsections.

5.2. Empirical results including SIC-based knowledge specialization variables

Table 4 repeats the analyses in Table 3, but adds the two specialized knowledge variables $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ that rely on our classification of SIC codes in Table 2. The classification of SIC codes in Table 2 that underlies these variables is intended to capture differences across industries of technical knowledge acquired by experience and knowledge assembled by aggregation. The variables are intended to capture both the average level of such knowledge in the firm and incremental knowledge specialization at the second level. We expect that these two variables measure aspects of knowledge not measured by growth and uncertainty.

Empirically, the variables $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ increase the regressions' explanatory power and have significant coefficients with the same sign as the other three specialized knowledge variables (GROW, DUNC and SIZE). This suggests all five variables reflect specialized knowledge. $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$, however, appear to be capturing different aspects of specialized knowledge, since their inclusion has little effect on the significance of the GROW and DUNC coefficients. Including $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ in the regression slightly reduces the significance of DUNC and slightly increases the significance of GROW.

On the other hand, including $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ reduces the magnitude and significance of the coefficients on the externalities and regulation variables substantially. Comparing corresponding columns in Tables 3 and 4, adding $\overline{\mathrm{KS}}$ and $\Delta\mathrm{KS}$ roughly halves the coefficient on the externalities variables and reduces the coefficient on REG by about one third. As we expect, $\overline{\text{KS}}$ and ΔKS pick up the extent to which the EXT variables reflect specialized knowledge rather than externalities. Further, unlike Table 3, we can no longer reject the hypothesis that the coefficients on the EXT dummies are equal; the probability of this F-statistic now ranges from 0.12 to 0.5.

The coefficient of $\overline{\text{KS}}$ is positive and significant at least at the 0.07 level in all six regressions. ΔKS's coefficient is positive and significant at the 0.08 level in all but regression (6). The regressions in Table 4 are not independent; however, the coefficients on the five variables measuring knowledge specialization have the same sign in all six regressions. The adjusted R^2's exceed the corresponding numbers in Table 3 in all six cases.

In Table 3, EXT3 is significant at the 0.10 level in all three regressions in which it appears; however, in Table 4, it is not significant in any regression at the 0.35 level. The significance of EXT4 is also reduced substantially in Table 4 as is the significance of EXTLOB. However, the coefficients of EXT4 and EXTLOB remain significant at least at the 0.02 level in all the regressions in which they are the only EXT variables. In regressions three to five, the coefficients of REG are significant at least at the 0.002 level in Table 3; however, in Table 4, the equivalent level is 0.04.

Overall, including the $\overline{\text{KS}}$ and ΔKS variables improves the fit and specification of a model that has considerable ability to explain decentralization without them. Regression five in Table 4 is a good candidate for predicting decentralization outside the sample: It has the equal highest explanatory power, is well specified, and uses independent variables that are available without using a questionnaire.

5.3. Other specification tests

We conduct a variety of specification tests that are not reported in detail. The following is a summary of the results of those tests:

1. There is no evidence that industry dummies have any incremental explanatory power over the included variables. See the relevant F-tests in column 6 in each of Tables 3 and 4.
2. Except for two regressions in Table 3 that we argue exclude relevant explanatory variables, there is no evidence of any form of misspecification or of heteroscedasticity. See the White statistics in Tables 3 and 4.[21]
3. There is no evidence that variables predicted by our theory are proxying for something simple, such as the number of lines of business (SNLOB).
4. The results are insensitive to measurement of the DUNC variable and to different definitions of 'regulated'.

None of our diagnostic tests uncover any evidence that our variables are capturing anything other than the relations we predict. We conclude that decentralization at firms' second levels is robustly related to measures of knowledge transfer costs, control costs and regulation.

[21] White's asymptotic χ^2 statistic tests the joint hypothesis that a regression model is well specified and homoscedastic.

Table 4
Determinants of decentralization including knowledge specialization: dependent variable DEC

	Predicted sign	Unregulated firms (1)	All firms (2)	All firms (3)	All firms (4)	All firms (5)	All firms[a] (6)
Sample size in 1987[b]		93	121	121	121	121	121
Intercept	?	0.28	– 0.06	0.20	0.17	0.23	0.34
t		1.53	– 0.40	1.07	0.98	1.33	1.50
Prob. (*t*)		0.13	0.69	0.29	0.33	0.19	0.14
$\overline{\text{KS}}$	?	0.38	0.42	0.34	0.35	0.31	0.26
t		4.01	4.57	3.53	3.83	3.21	1.84
Prob. (*t*)		0.0001	0.0001	0.0006	0.0002	0.0017	0.069
ΔKS	?	1.01	1.00	0.93	0.98	0.78	0.77
t		2.39	2.27	2.13	2.33	1.80	1.65
Prob. (*t*)		0.019	0.025	0.036	0.021	0.074	0.103
GROW	?	0.11	0.17	0.14	0.14	0.14	0.12
t		1.89	2.79	2.21	2.33	2.28	1.79
Prob. (*t*)		0.063	0.0062	0.029	0.022	0.025	0.077
DUNC	?	0.26	0.90	0.53	0.52	0.47	0.42
t		0.84	3.23	1.65	1.65	1.48	1.29
Prob. (*t*)		0.40	0.0016	0.103	0.10	0.14	0.201
SIZE	?	0.15	0.19	0.14	0.12	0.13	0.13
t		0.69	0.86	0.65	0.58	0.64	0.62
Prob. (*t*)		0.49	0.39	0.51	0.56	0.52	0.54
EXT2	–	– 0.01	– 0.02	– 0.03			
t		– 0.13	– 0.22	– 0.35			
Prob. (*t*)		0.45	0.423	0.36			

EXT3	–	– 0.04	– 0.03	– 0.04			
t		– 0.43	– 0.39	– 0.43			
Prob. (t)		0.33	0.35	0.34			
EXT4	–	– 0.11	– 0.18	– 0.18	– 0.15		
t		– 1.16	– 1.83	– 1.87	– 2.13		
Prob. (t)		0.125	0.035	0.032	0.018		
EXTLOB	–					– 0.19	– 0.23
t						– 2.49	– 2.77
Prob. (t)						0.0072	0.0033
REG	–			– 0.20	– 0.20	– 0.19	– 0.23
t				– 2.32	– 2.33	– 2.19	– 1.74
Prob. (t)				0.011	0.011	0.015	0.04
Adjusted R^2		0.26	0.48	0.50	0.51	0.51	0.51
Prob. F (All coefficients = 0)		0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
Durbin–Watson (SIZE)[c]		2.04	1.90	1.94	1.94	1.92	2.21
Prob. (White Statistic)		0.64	0.72	0.54	0.32	0.69	0.28
Prob. F (EXT2 = EXT3 = EXT4)		0.50	0.12	0.13			
Prob. F[d] (All theory variables = 0)							0.0001
Prob. F (All Industry Dummies = 0)							0.50

[a] Coefficients and t-statistics on eight industry dummies are not reported.

[b] DEC = Decentralization. Equals one if the second level units are all profit centers, zero if they are all cost centers, and one-half if there are both profit and cost centers. $\overline{KS}$ = Average knowledge specialization for the industries in which the firm operates. NLOB = Number of lines of business (four-digit SIC codes) the firm operates in. SNLOB = Number of lines of business divided by sample maximum NLOB. ΔKS = Incremental knowledge specialization of multiple lines of business, SNLOB(1 – $\overline{KS}$). GROW = Growth measured by the ratio of market value to book value of the firm. UNC = Std. dev. of rate of return on equity for the 60 months ended December 1987. DUNC = UNC/SQRT{1/NLOB+[(NLOB – 1)/NLOB] × CORR}. CORR = Average off diagonal correlation among the firm's lines of business at the two-digit SIC level. SIZE = Sales for 1987 as per Compustat. EXTi = Externalities among business units. EXT2, EXT3 and EXT4 are coded one for related businesses, dominant business and single business, and zero otherwise. EXTLOB = Coded one if all the firm's SIC codes are in the same two-digit group, zero otherwise. REG = Unity if the firm's primary industry is utility, transportation or communications.

[c] The Durbin-Watson statistic with the residuals sorted by size. This is a test for nonlinearity. The Durbin-Watson when the residuals are sorted by the uncertainty variable is similar to those reported by size.

[d] Theory variables are $\overline{KS}$, ΔKS, GROW, DUNC, SIZE, EXTLOB, and REG.

6. Application of the model to Caterpillar and General Electric

As a reality check, we asked one of our executive professor colleagues to a priori assess the structure of a few of our sample firms. He assessed General Electric as decentralized and Caterpillar as centralized. We searched the Wall Street Journal using the Dow Jones News/Retrieval service for the period 1990–1993 for references to these two firms. Using the words 'centralized', 'decentralized', and 'structure', we found references only to Caterpillar.

The independent variables in the model that uses non-questionnaire data (column 5 of Table 4) are measured in 1987. At that time, Caterpillar was organized on a functional basis which normally implies centralization (Wall Street Journal, January 30, 1990, p. B12, 'Who's News'). However, also in 1987, faced with competition from abroad (in particular, Komatsu), Caterpillar launched its 'Plant with a Future Program' to overhaul its factories, installing robots and streamlining assembly systems (see Wall Street Journal, April 6, 1990, p. A1, 'Currency squeeze: Caterpillar sees gains in efficiency imperiled by strength of dollar'). Later, in 1990, Caterpillar announced 'a major reorganization of its management structure designed to push decision-making downward in the organization' (Wall Street Journal, January 30, 1990, 'Who's News', p. B12). This led to an emphasis on profit centers: 'To achieve a "flatter" and more flexible structure, Caterpillar is replacing its function-oriented hierarchy with highly autonomous profit centers and support divisions.'

In responding to our 1988 questionnaire, Caterpillar management describe the firm as using both profit and cost centers, so its decentralization was scored as 0.5 (mixed). The predicted dependent variable for Caterpillar using the estimated equation in column (5) of Table 4 is 0.716. The cut-off values for predicting decentralization, mixed or centralized that are symmetric around 0.5 and minimize the number of misclassifications are 0.72 and 0.28. At 0.716, Caterpillar would be classified as mixed consistent with the management response, but clearly, it is marginal between mixed and decentralized.

By 1992, the model implies greater decentralization for Caterpillar. Using 1992 data, the predicted decentralization for Caterpillar is 0.824. This is primarily due to the externalities variable (EXTLOB) decreasing from one to zero. In 1987, all of Caterpillar's lines of business fall within the same two-digit group (SIC code 35 machinery except electrical); in 1992, they do not. The new lines of business are concrete products (except block and brick—SIC code 3272), short-term business credit institutions (6153), accident and health insurance (6321) and fire, marine and casualty insurance (6331). We do not know whether the added lines of business are a cause or an effect of the organizational change. The implications of the model excluding the knowledge specialization variables for Caterpillar's decentralization in 1987 and 1992 are essentially the same as those reported here. The Caterpillar case is consistent with the regression results.

The predicted decentralization for General Electric using the model in column (5) of Table 4 is 0.92 in 1987 and is 0.88 in 1992. GE's management reports in the 1988 questionnaire that all the units at the second level are organized as profit centers so GE's decentralization variable is scored as 1.0.

7. Summary and conclusions

We expand on the analysis and evidence in Chandler (1962, 1977), Williamson (1975), Vancil (1978) and Jensen and Meckling (1992) to provide evidence that decentralization of firms is robustly related to characteristics of firms' investment opportunity sets. Those characteristics are the specialization of knowledge generated by firms, the externalities among a firm's investments, and regulation. Evidence on the association between decentralization and these characteristics is generated using a questionnaire and data from public sources.

The evidence is consistent with the expected associations. The empirical associations are generally significant and always have the same signs across different specifications. We predict the signs of two variables' associations with decentralization (externalities and regulation). The sign of the association of decentralization with the other variables depends on the relative magnitudes of partial derivatives we cannot observe. However, the coefficients on the five variables that measure knowledge specialization should have the same sign. The evidence is consistent with all these predictions. Larger firms with growth options that face greater uncertainty generate knowledge that is more costly to transfer to decision makers. The results are essentially invariant to alternative measures of relevant characteristics of the firm. One specification uses questionnaire data only for the dependent variable and so can be used to predict decentralization for firms outside the sample.

The evidence is consistent with knowledge transfer costs being, on average, **relatively** more important than control costs in the decentralization decision. More decentralized firms tend to generate more specialized knowledge, have less externalities among the firms' investments, have higher growth and greater uncertainty about the firms' returns. Decentralized firms also tend to be larger and unregulated. The evidence not only supports the predicted associations between decentralization and other variables, but also it is robust. There is no evidence of nonlinearity with respect to the continuous independent variables and the coefficients are robust to excluding some of the firms and to different ways of measuring variables. Except for the models that exclude two knowledge specialization variables, we cannot reject the hypothesis that our models are well specified and homoscedastic, despite the fact that our independent variables are mismeasured, and some of the explanatory variables are endogenous.

An important caveat that indicates the nature of the endogeneity has to do with the acquisition of knowledge. We argue that the allocation of decision rights depends on the specialization of knowledge generated by the firm. However, allocating decision rights to someone changes the nature of the knowledge they acquire. In particular, they might acquire more or different knowledge from that acquired in the absence of the decision rights. Further, as noted in the Caterpillar case, decentralization of decision rights can change the measured externalities among the firms' investments. While we speculate that these are second order effects, we have no way of testing this.[22]

[22] Endogeneity is one explanation for the collinearity among explanatory variables we observe in Appendix A.

Appendix A. Pearson correlation coefficients among variables and Prob. (Rho = 0)

	DEC	$\overline{KS}$	SNLOB	ΔKS	GROW	UNC	DUNC	SIZE	EXT	REG
DEC	1.0000	0.5781	0.4780	0.0789	0.3178	0.3505	0.3777	0.1536	– 0.5010	– 0.5765
	0.0000	0.0001	0.0001	0.3894	0.0002	0.0001	0.0001	0.0925	0.0001	0.0001
$\overline{KS}$	0.5781	1.0000	0.5208	– 0.3203	0.2522	0.2060	0.2211	0.1211	– 0.5318	– 0.5252
	0.0001	0.0000	0.0001	0.0003	0.0053	0.0234	0.0148	0.1856	0.0001	0.0001
SNLOB	0.4780	0.5208	1.0000	0.3821	0.1247	0.1136	0.1541	0.2354	– 0.5395	– 0.3545
	0.0001	0.0001	0.0000	0.0001	0.1727	0.2147	0.0915	0.0093	0.0001	0.0001
ΔKS	0.0789	– 0.3203	0.3821	1.0000	– 0.1447	0.0771	0.1318	0.2146	– 0.0953	0.0122
	0.3894	0.0003	0.0001	0.0000	0.1132	0.4006	0.1494	0.0181	0.2981	0.8942
GROW	0.3178	0.2522	0.1247	– 0.1447	1.0000	0.0063	– 0.0007	– 0.0473	– 0.2429	– 0.2713
	0.0002	0.0053	0.1727	0.1132	0.0000	0.9447	0.9938	0.6060	0.0073	0.0026
UNC	0.3505	0.2060	0.1136	0.0771	0.0063	1.0000	0.9893	– 0.0997	– 0.1724	– 0.5416
	0.0001	0.0234	0.2147	0.4006	0.9447	0.0000	0.0001	0.2761	0.0585	0.0001
DUNC	0.3777	0.2211	0.1541	0.1318	– 0.0007	0.9893	1.0000	– 0.0917	– 0.1979	– 0.5377
	0.0001	0.0148	0.0915	0.1494	0.9938	0.0001	0.0000	0.3169	0.0295	0.0001
SIZE	0.1536	0.1211	0.2354	0.2146	– 0.0473	– 0.0997	– 0.0917	1.0000	– 0.0186	– 0.0864
	0.0925	0.1856	0.0093	0.0181	0.6060	0.2761	0.3169	0.0000	0.8394	0.3456
EXT	– 0.5010	– 0.5318	– 0.5395	– 0.0953	– 0.2429	– 0.1724	– 0.1979	– 0.0186	1.0000	0.3553
	0.0001	0.0001	0.0001	0.2981	0.0073	0.0585	0.0295	0.8394	0.0000	0.0001
REG	– 0.5765	– 0.5252	– 0.3545	0.0122	– 0.2713	– 0.5416	– 0.5377	– 0.0864	0.3553	1.0000
	0.0001	0.0001	0.0001	0.8942	0.0026	0.0001	0.0001	0.3456	0.0001	0.0000

DEC = Decentralization. Equals one if the second level units are all profit centers, zero if they are all cost centers and one-half if there are both profit and cost centers. $\overline{KS}$ = Average knowledge specialization for the industries in which the firm operates. NLOB = Number of lines of business (four-digit SIC codes) the firm operates in. SNLOB = Number of lines of business divided by sample maximum NLOB. ΔKS = Incremental knowledge specialization of multiple lines of business, SNLOB($1-\overline{KS}$). GROW = Growth measured by market to book ratio. UNC = Std. dev. of rate of return on equity for the 60 months ended December 1987. DUNC = UNC/SQRT{1/NLOB+[(NLOB – 1)/NLOB] $\times$ CORR}. CORR = Average off diagonal correlation among the firm's lines of business at the two-digit SIC level. SIZE = Sales for 1987 as per Compustat. EXT = Externalities among business units. EXT is coded one through four for unrelated businesses, related businesses, dominant business and single business. REG = Unity if the firm's primary industry is utility, transportation or communications.

Two of our four measures of specialization of knowledge depend on an ex ante classification of the specialization of knowledge generated by different industries. While there is an element of subjectivity inherent in this classification, it stems from the theory, and is made a priori. We believe it reflects the notions of specialized, assembled and nonspecialized knowledge. Further, a robust relation exists between decentralization and the other investment opportunity set characteristics when the two variables are excluded.

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