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Outsourcing when Investments are Specific and Complementary

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Abstract

Using the universe of large Canadian manufacturing firms in 1988 and 1996, we investigate to what extent firms' outsourcing decision can be explained by a simple property rights model. A novel aspect of the data is the availability of component level information on outputs as well as inputs which permits the construction of a very detailed measure of vertical integration. Moreover, we construct five different measures of technological intensity to proxy for investments that are likely to be specific to a buyer-seller relationship. Our main findings are that (i) greater specificity makes outsourcing less likely; (ii) complementarities between the investments of the buyer and the seller are also associated with less outsourcing; (iii) only when we focus on the range of transactions with low complementarities do we find support for several nuanced predictions of the property rights model.

Keywords: Property rights theory, complementarity, asset specificity, vertical integration

JEL codes: L14, D23

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1 Introduction

The principal objective of this paper is to understand how producer and supplier investment intensities influence the optimal ownership structure. In particular, we ask whether the observed relationship between technological intensities and outsourcing patterns in Canadian manufacturing is consistent with predictions of the property rights theory of the firm.

Technology is likely to be an important factor in firms' outsourcing decisions. The spread of information and communication technology has certainly contributed to the increased fragmentation of production across firms, potentially located in different countries (Abramovsky and Griffith 2006). More generally, it is sometimes argued that technology enhances outsourcing benefits, for example allowing greater specialization, and firms would be expected to become smaller and/or more decentralized (Brynjolfsson, *et al.* 1994; Quinn 2000). At the same time, new technologies could raise the value of assets within an existing relationship more than outside it, for example because of greater customization. Firms fearing expropriation of investments could be expected to reduce outsourcing (Williamson 1985).

Little systematic evidence exists on how technological intensity influences outsourcing and under what conditions. One example, Mol (2005) shows that in the Dutch manufacturing sector the relationship between R&D intensity and outsourcing recently switched from negative to positive.[1] While concerns over opportunism and expropriation still exist, he conjectures that a higher scale of production, increased specialization between industries, and more sophisticated relational contracting now make it more advantageous to outsource some R&D intensive activities. A second example, discussed in greater detail in the next section, Acemoglu, Aghion, Griffith, and Zilibotti (2005) (henceforth AAGZ) tests implicitly between the predictions of transaction cost economics (TCE) and the property rights theory (PRT). TCE predicts that, all else equal, higher asset specificity makes integration more likely, irrespective of which firm is making the specific investments. In contrast, the PRT distinguishes theoretically between forward and backward integration, but this distinction tends to be unobservable. Assuming only one type of integration is empirically relevant, producer and supplier investments should have opposite effects on the probability of outsourcing, which is borne out in their sample.

Our empirical work is guided by an explicit theoretical model that features producer and supplier investments which are both specific to the relationship and potentially exhibit complementarities. As discussed in Whinston (2003), there are many ways to operationalize the PRT, leading to different predictions. We restrict the effects investments can have in the model in a number of plausible ways to obtain testable predictions. One crucial aspect that all PRT approaches share is that allocating control rights has benefits *and* disadvantages. It will strengthen the investment incentives of the controlling firm, at the expense of weaker incentives for the acquired firm. Our model shares this feature with the existing empirical work, which is reviewed in the next section.

[1] Mol (2005) contains references to several other studies predicting the effect of technology on outsourcing going in either direction.

A novel feature of our theoretical model is to incorporate complementarities between the investments made by the two firms that are transacting—"cooperative" investments in Che and Hausch (1999). These authors have shown that when committing not to renegotiate is impossible, contracts are without value in this situation, making the PRT framework particularly appropriate.

Following the literature that studies externalities between different actions, we call these "complementary" investments — see Milgrom and Roberts (1990) for a landmark application and Athey and Stern (2003) for an overview of estimation methodologies. The concept is frequently relied upon to explain why several activities in a firm's internal organization tend to be adopted together, but it has much wider applicability. In general, two activities are complementary if adoption of one activity increases the marginal productivity of a second activity.[2] A number of papers, reviewed in the next section, have studied how complementarities between different actions of one firm influences the optimal level of outsourcing. Roberts (2004) (p. 218) has suggested that complementarities between investments of different firms could serve as a theory of the firm, but we have not seen previous work that models this explicitly.[3]

With complementarities, one firm's investment raises the marginal effect of the other firm's investment. Off the equilibrium path in a backward vertically integrated situation, a fraction of the supplier's investment is lost to the producer (owner) if investments are not fully appropriable. Complementarities will increase the wedge between the marginal return of the owner's own investment under joint production versus a break-up. In relative terms, it reduces the owner's outside option more, which increases the investment incentives for the subsidiary and ameliorates the principal form of underinvestment under integration. We will show formally under what circumstances complementarities raise the likelihood of vertical integration.

Note that our terminology is intended to capture something different from "complementarities" in Hart and Moore (1990), which refers to the extent an investment remains productive if it is separated from the human capital of the investor. They use complementarity to describe a property of a created asset and an asset that is intrinsically connected to the investing firm. In our model, the only assets are those created by the investments—there is no human capital—and we use complementarity to describe a property of the investments made by different firms. What Hart and Moore (1990) calls investments that are "perfectly complementary," we will call investments that are "impossible to appropriate." In both cases, marginal investment returns on disagreement payoffs under nonintegration are reduced to zero, leading to the prediction that such a feature will increases the likelihood of investments being co-owned.

We investigate the make-or-buy decision of Canadian manufacturing firms and focus on technologies that are likely to be important in production. Many technologies come embodied in assets which are to varying degrees specific to the trading relation they are employed in. Investments can

[2]If the activities are continuous variables, the cross-partial derivative of the objective function (profit, productivity) with respect to both activities is positive (negative if the objective is the cost function).

[3]Lindbeck and Snower (2003) contains some similar ideas, but they tend to focus on economies of scale and scope within a single production factor.

also be specific to a particular producer-supplier relationship if they serve to customize an input. With imperfect contractibility, such asset specificity gives rise to a potential hold-up problem.

The empirical approach is related to the work of AAGZ on the U.K. manufacturing sector, but our data has three notable benefits. First, as we observe inputs and outputs at the plant level at very disaggregate level (6-digit commodities), we do not need to rely on input-output tables to construct our outsourcing measure. Rather, for each plant we can check directly whether any of its inputs are produced by another plant owned by the same firm.[4] The cost-share of an input is also measured at the firm-commodity level.

Second, linking our sample to the national survey on technology adoption, we can construct several measures of technological intensity at the industry level. In addition to R&D intensity and the capital-labor ratio, similarly as AAGZ, we construct measures of advanced technology use, frequency of innovative activities, and importance of human capital. These latter measures might have a more direct link to investments in specific assets or to efforts to customize inputs that feature in the theory. In addition, we can use the product detail to classify each input as a homogenous or differentiated good, following Rauch (1999). This provides an observable indicator of how likely it is that the PRT framework—which has asset specificity and the existence of quasi-rents at its core—is empirically relevant.

Third, we can construct proxies for several of the most important variables in the model. This is an important aspect of our work as it links the different theoretical concepts to observable variables. The extent of production complementarities is measured by the overlap in inputs between the producer's core output and the input under study. We construct a number of proxies for specificity and the outside options of the firms. The different investment intensities have a natural ranking in terms of appropriability.

In the PRT framework, various aspects of investments influence the theoretical predictions.[5] Mapping the theoretical constructs into observable measures is a delicate undertaking. We benefit from unusually rich data that we can use to investigate whether the organization of transactions and investments that are most likely to satisfy the PRT assumptions follows the PRT predictions. One would not expect the PRT approach to be able to explain the outsourcing-integration trade-off for all transactions in the economy. We will provide evidence that where we would expect the theory to apply, observed patterns are in line with the predictions.

In particular, the results concord more with the theory if the inputs are differentiated products. Integration becomes less attractive if the returns on investment outside the relationship improve, as proxied by the number of alternative clients. AAGZ has shown theoretically and provided evidence that the predictions are strengthened if an input makes up a larger share of the producer's cost, which also holds in our data. In addition, we find that sufficiently large complementarities

[4]Because most input-output tables are an aggregation of plant-commodity level information, our measures are more detailed. If one plant does not use all of the inputs that the set of plants in its industry uses, we avoid introducing spurious observations in our analysis.

[5]Different parameters in the theoretical capture the extent of specificity, complementarities, appropriability.

will trump PRT considerations and lead to integration even if both firms make important specific investments. Finally, all predictions depend on the ease with which the owner of an integrated firm can appropriate the subsidiary's investment, which varies across the different measures of technology intensity. If appropriability increases, integration becomes less attractive.

Our results indicate, first, that specificity is an important determinant of the vertical integration or outsourcing decision of manufacturing firms. Second, we find that production complementarities increase the likelihood of integration, consistent with our theory. Third, turning to the more nuanced predictions of the PRT, the effects of producer and supplier technological intensity on the outsourcing probability should depend crucially on the relative magnitudes of each firm's investment intensity. Greater asymmetry between these intensities, which could mean more investments by producers *or* suppliers, should lead to integration. We do find strong empirical support for the augmented PRT predictions, but only for the range of transactions where complementarities between producer and supplier investments are low. Investment asymmetries lead to integration: producer investments lead to integration if they dominate, but to outsourcing if supplier investments are more important (and vice versa for supplier investments). These predictions are reinforced if the cost share is large, and if investments are more specific or harder to appropriate.

The remainder of the paper is organized as follows: Section 2 discusses empirical approaches to test the PRT and the existing evidence. Section 3 introduces a bilateral trading model with complementarities and derives a number of theoretical predictions. The empirical specification is provided in Section 4 and the data is described in Section 5. Section 6 discusses the results and lessons from the analysis are summarized at the end.

2 Empirical tests of the property rights model

An important feature of both the PRT and TCE is the existence of specific investments which have a greater value within the relationship than outside it. Researchers have tested the TCE model by verifying whether observable measures of asset specificity—plausibly related to appropriable quasi-rents—are associated with an increased probability of vertical integration.[6] By and large this has proven to be the case, see surveys by Joskow (1988) and Shelanski and Klein (1995). However, as Whinston (2003) illustrates clearly for a number of prominent studies, such evidence in support of TCE does not automatically carry over to the PRT.

One of the unique features of the PRT is the indivisibility of control.[7] In contrast with the TCE approach, each division of an integrated firm is explicitly assumed to maximize its own profit, choosing investments noncooperatively, just like two independent firms that are transacting in the

[6]The TCE approach, see for example Williamson (1979), posits that when quasi-rents are present, production will be inefficient as parties engage in costly activities to appropriate them. Without formally modeling the resolution of the hold-up problem, TCE predicts that we are more likely to observe outsourcing when the risk of hold-up is small.

[7]The PRT's focus on *ex ante* investment versus TCE's focus on *ex post* adaptation seems mostly a matter of modeling convenience, as noted by Whinston (2003) (footnote 6). Klein et al. (1978) (p. 301) acknowledges explicitly that distortions of *ex ante* investments, which give rise to the quasi-rents in the first place, are likely.

market. Klein, Crawford, and Alchian (1978) note explicitly that the defining difference between a long-term contract and vertical integration is in the possibility of (greater) postcontractual opportunistic reneging in the former organizational form. While conceding that "vertical integration does not completely avoid contracting problems (footnote 4)," they maintain that "the crucial assumption underlying the analysis of this paper is that, as assets become more specific and more appropriable quasi rents are created (...), the costs of contracting will generally increase more than the costs of vertical integration. Hence, ceteris paribus, we are more likely to observe vertical integration." (Klein et al. (1978) p. 298).

In contrast, the optimal organizational form in the PRT depends crucially on the relative marginal effect of each firm's investment rather than on the absolute size of the appropriable quasi-rent. In an integrated firm, investment incentives of the owner are enhanced but those of the subsidiary are weakened. While a literal interpretation of the PRT model leads to implausible predictions, as illustrated by Holmstrom (1999), the model is extremely useful to highlight the importance of exit rights as an incentive mechanism. The marketability of a firm's investments is an important disciplining device for its contracting party.

A few empirical studies have found support for the PRT by looking in detail at one specific industry. Woodruff (2002) studies the ownership structure between retailers and producers in the made-to-order Mexican footwear industry. He finds opposing effects of specificity on integration, depending on which party is making the specific investments. Greater product variety or higher quality materials, two attributes that arguably increase the hold-up risk mostly for the producer, are positively associated with integration. However, increased fashion turnover, which puts the onus on the retailer to learn consumers' taste, is associated with less integration. Under the maintained assumption that the (much smaller) retailers will never want to integrate backward into production, all three patterns are consistent with the PRT, while the TCE would predict more integration also in the latter case.

Baker and Hubbard (2003) studies the diffusion of on-board computers in the U.S. trucking industry and finds that it lead to a greater use of internal divisions, as opposed to for-hire carriers. Their interpretation is that the ability to monitor the agent (driver) more effectively lead to diminished scope for underinvestment (in driving effort) and reduced the benefit of relying on owner-operators.

A number of papers in international trade have also adopted the PRT framework. Work in this field is facilitated by the fact that official statistics distinguish between transactions occurring within and between firms. Antràs (2003) compares across industries the share of U.S. exports that consists of intrafirm trade and finds that this fraction is increasing in the capital-labor ratio. Assuming that capital is relationship-specific, he justifies this pattern as the optimal outsourcing decision in a PRT model. Another application in international trade is Feenstra and Hanson (2005) which reconciles the observed allocation of ownership and control in China's export processing sector with the predictions of an augmented PRT model. They find that in most cases foreign firms retain ownership and control of the plant, while the local partner controls input-purchasing.[8]

AAGZ (Acemoglu et al. 2005) employs a novel approach to overcome data limitations on the ownership structure in the economy at large. For the universe of manufacturing firms in the U.K., they verify whether a producer (firm) owns a plant in any of the industries that the national input-output table indicates to be supplier-industries. Their main finding is that increased R&D intensity in the producer or supplier industry has opposite effects on the likelihood that a firm owns plants in both industries. The signs on the effects are consistent with the relevant trade-off in the data being between backward vertical integration (producer owns supplier) and outsourcing. In this case, integration strengthens producer incentives, while outsourcing encourages supplier investment. They note that the asymmetric effects are consistent with the PRT, while TCE considerations would suggest that any increase in the importance of specific investments (R&D) would make integration more likely.

The discussion in Whinston (2003) indicates that a rich specification of (cross-) investment effects—allowing for both firms' investments to affect both firms' outside options in the integrated and outsourced organizational form—mostly leads to ambiguous effects. In order to obtain unambiguous predictions, AAGZ restrict the impact of investments on the outside options in several respects.[9] Given that we also attempt to investigate the predictive power of the PRT exploiting variation across industries, we will employ many of the same restrictions to get unambiguous predictions.

As mentioned earlier, one important addition we introduce in the PRT model is to allow for complementarities. The marginal contribution of one firm's investment can be increasing in the investment level of the second firm. Papers in the complementarity literature model this with interactions of investments in the objective function, and we will follow that modeling strategy.[10]

A number of papers with complementarities have discussed the impact on the theory of the firm. Milgrom and Roberts (1990) argues that technology will make equipment more flexible and less specific, reducing the incentive for vertical integration. It is also mentioned that the theory could predict less outsourcing if demand was more uncertain, requiring increased coordination between tasks, but only if coordination could be provided more cheaply within the firm. They discard this possibility as inconsistent with anecdotal evidence in the press. Novak and Stern (2003) develops a model where outsourcing of one automotive component can create externalities for other sourcing decisions. The source of the externality in their model is the interdependency in coordination efforts or the need for disclosure of proprietary trade secrets. Outsourcing of one component is predicted to increase the likelihood that other components will be outsourced as well. They find support for this in a confidential data set for the automotive industry.

[8] More empirical work on this subject is ongoing in the trade literature, see for example Nunn and Trefler (2007).

[9] Under the following restrictions on marginal investment returns, the model in Whinston (2003) is exactly equal to the model in Acemoglu et al. (2005): $\sigma_{B1} = \sigma_{S1} = \sigma_{B0} = \beta_{S0} = 0$, $\sigma_{S0} < \alpha_S$, $\beta_{S1} < \alpha_S$, $\beta_{B0} < \alpha_B$, $\beta_{B1} = \alpha_B$.

[10] Important papers in this literature are Milgrom and Roberts (1990) (theory), Athey and Stern (2003) (empirical methodology), and Arora and Gambardella (1990) and Ichniowski, Shaw, and Prennushi (1997) are important applications.

Only Roberts (2004) considers complementarities between investments of different firms. He suggests that it makes coordination more important and that it could be a motivation for integration. This prediction is in line with our findings, at least for some parameter values. Before turning to the evidence, we first illustrate how the existence of complementarities modifies the standard PRT model.

3 Model

Consider a bilateral trade setting between a producer (P) that purchases an input from a supplier (S). Both firms can make unobservable, noncontractible, investments that raise the value produced within the relationship, for example by investing in relationship-specific assets or customizing an input. The joint surplus created in the relationship takes the following form:

$$F(x_P, x_S) = \alpha_P x_P + \alpha_S x_S + \alpha_{PS} x_P x_S. \tag{1}$$

The x variables denote the investments of the two firms. Each has a direct effect on the surplus, α_P and α_S, and an additional indirect effect, α_{PS}. The interaction term is what distinguishes our approach from earlier models. It represents complementarities: the marginal value of each firm's investment is increased if the other firm invests more ($\partial^2 F/\partial x_P \partial x_S > 0$). Complementarities are independent of the organizational form. However, they are only realized if both investments are combined in production, i.e. under joint production or when one firm controls the outcomes of both investments (integration).

We assume that a generic input can be produced at zero cost or without any relationship-specific assets. The costs of the specific investments for both parties are quadratic,

$$C_P(x_P) = \frac{1}{2}x_P^2 \qquad \text{and} \qquad C_S(x_S) = \frac{1}{2}x_S^2. \tag{2}$$

The timeline of decisions is as follows. First, the parties decide on an organizational form: the producer buys the supplier, i.e. backward vertical integration (VIB); unintegrated production or outsourcing (O); or the supplier controls the firm, i.e. forward vertical integration (VIF). Transfers between the firms before any investments are made will guarantee that each firm receives at least its reservation payoff and that the adopted organizational form maximizes joint profits. Second, under each of the three organizational forms, investments are made noncooperatively by both parties. Third, the surplus is divided between the two firms using Nash bargaining, with each firm receiving equal weight.

If *ex post* the relationship breaks down and no joint production takes place (which does not happen on the equilibrium path), each party receives its outside option. This depends on the ownership form that has been put in place before investments are made. If the producer owns the supplier, the outside options are as follows:

$$\begin{aligned} \pi_P^{VIB}(x_P, x_S) &= F(x_P, \lambda x_S), \\ \pi_S^{VIB}(x_P, x_S) &= 0. \end{aligned} \tag{3}$$

The supplier loses the customized input or its asset, as it is owned and controlled by the producer, and receives nothing. It could make generic inputs for another firm and sell them at cost, but no profit will be made. Ownership gives the producer the benefit of the customized input, but we assume it does not yield the same value as in harmonious joint production. For example, some tacit knowledge of how to use the input is not passed on or some final customization touches would only be put in place by the supplier at the last minute. As a result, only a fraction $\lambda \in [0, 1]$ of the supplier's investment will be productive. An important departure from the models in Whinston (2003) or AAGZ is that with complementarities the loss of a fraction of the supplier investment also reduces the marginal return of the producer's own investment. The outside options in the forward vertical integration relation are symmetric.[11]

If the parties had formed an outsourcing arrangement, giving each control over its own investment in the case of a break-up, the outside options would be

$$\begin{aligned} \pi_P^{O}(x_P, x_S) &= F(\theta x_P, 0), \\ \pi_S^{O}(x_P, x_S) &= F(0, \theta x_S). \end{aligned} \tag{4}$$

As each firm retains control over its own investment, the complementarities in equation (1) will not be realized if the relationship breaks up. Moreover, given that the producer has to find another partner to supply it with generic inputs that do not match as well with its own investments and the supplier has to find another producer that requires somewhat different customization, we assume that the value of their investments will be reduced to a fraction $\theta \in [0, 1]$ of their value within the original relationship, again modeled symmetrically for the two firms. It is likely that the loss when the specific investments are not combined in production will be larger than the loss when at least one party controls both investments, i.e. $\theta \leq \lambda$, but we do not impose it.[12]

[11] As we have no reason to assume otherwise, we model the same fractional loss in producer investments (λ) to the supplier.

[12] Our model imposes a number of restrictions on the model of Whinston (2003), which we share with AAGZ, to obtain unambiguous predictions on the effect of technology intensities on organizational form. If we limit attention to situations where the supplier-producer link is very strong ($\phi = 1$ in AAGZ), the following restrictions are important:

1. Under integration, the return on investment in the outside option of acquired firm is low. We followed AAGZ in specifying that $\sigma_{P1} = \sigma_{S1} = 0$, but weaker assumptions are certainly possible. For example, Hart (1995) (chapter 2) only specifies that $\sigma_{S1} < \sigma_{S0} < \alpha_S$ and obtains similar predictions.

2. Still under integration, the return on self-investment in the outside option of the acquiring firm is high, but that on cross-investments by the acquired firm is low. We assumed that $\beta_{P1} = \alpha_P$ and $\beta_{S1} < \alpha_S$, but weaker assumptions, for example $\alpha_S > \beta_{P1} > \beta_{P0}$ as in Hart (1995), would not change the predictions. (Note that Hart (1995) uses a stronger restriction on cross-investments: $\beta_{S1} = 0$.)

3. In an outsourcing relationship, cross-investments are of no value ($\beta_{S0} = \sigma_{P0} = 0$) if production is not joint and the return on self-investments is lower outside the relationship than inside ($\beta_{P0} < \alpha_P$ and $\sigma_{S0} < \alpha_S$).

As a benchmark, the first best investments in the presence of complementarities maximize the aggregate welfare function:

$$W(\alpha,\lambda,\theta) \;=\; \alpha_P x_P + \alpha_S x_S + \alpha_{PS} x_P x_S - \frac{1}{2}(x_P)^2 - \frac{1}{2}(x_S)^2. \tag{5}$$

Solving the system of first order conditions for both decisions gives

$$x_P^* = \frac{\alpha_P + \alpha_{PS}\alpha_S}{1-\alpha_{PS}^2} \qquad \text{and} \qquad x_S^* = \frac{\alpha_S + \alpha_{PS}\alpha_P}{1-\alpha_{PS}^2}. \tag{6}$$

Both investments are increasing in each of the three parameters in the joint surplus production function. For $\alpha_{PS} = 0$ this boils down to the model in AAGZ. Given that the marginal investment costs are normalized to x_P and x_S, the model is only well-defined if $\alpha_{PS} < 1$. Even if one investment has no direct effect on the surplus production, say $\alpha_S = 0$, it will still not be set at zero as it has an indirect effect by raising the productivity of x_P if $\alpha_{PS} > 0$. It will be the case, though, that $x_P > x_S$.

Optimal investments under the different organizational forms will be decided by each party noncooperatively. Anticipating Nash bargaining (with equal weight for both parties) to split the surplus, firm $k \in \{P, S\}$ maximizes:

$$\max_{x_k} \pi_k^z(x_P, x_S) + \frac{1}{2}[F(x_P, x_S) - \pi_P^z(x_P, x_S) - \pi_S^z(x_P, x_S)] - C_k(x_k), \tag{7}$$

where the appropriate outside options for each organizational form $z \in \{VIB, O, VIF\}$ have to be substituted. As both firms take their decisions simultaneously, a Nash equilibrium of the noncooperative investment-game is obtained by the intersection of the two firms' best response functions.

Because the entire problem is set up symmetrically for the producer and supplier, we only have to solve for the determinants of the trade-off between backward vertical integration and outsourcing. The trade-off between forward vertical integration and outsourcing will be symmetric. Straightforward algebra on the first order conditions to the above problem in each case gives the following optimal investments:

$$x_P^{VIB} = \frac{\alpha_P + \frac{1-\lambda^2}{4}\alpha_{PS}\alpha_S}{1-\frac{1-\lambda^2}{4}\alpha_{PS}^2} \quad \text{and} \quad x_S^{VIB} = \frac{\frac{1-\lambda}{2}(\alpha_S + \alpha_{PS}\alpha_P)}{1-\frac{1-\lambda^2}{4}\alpha_{PS}^2}, \tag{8}$$

$$x_P^{O} = \frac{\frac{1+\theta}{2}(\alpha_P + \frac{1}{2}\alpha_{PS}\alpha_S)}{1-\frac{1}{4}\alpha_{PS}^2} \quad \text{and} \quad x_S^{O} = \frac{\frac{1+\theta}{2}(\alpha_S + \frac{1}{2}\alpha_{PS}\alpha_P)}{1-\frac{1}{4}\alpha_{PS}^2}. \tag{9}$$

Without complementarities, these results are consistent with those in AAGZ, and we can unambiguously say that comparing VIB to O, underinvestment is reduced for the producer, but exacerbated for the supplier.

With complementarities, this pattern will not necessarily hold anymore. A first thing to note is that the optimal investments under VIB are decreasing in λ, the fraction of the supplier's investment that can be appropriated by the producer in the case of a break-up. At the extreme, if $\lambda = 1$, the supplier will not invest anything, because the outside option of the producer equals the entire joint surplus. As a result, even though the producer has all the power in the relationship, only the direct effect of his investment will be realized and he will only invest α_P, which potentially falls far short of x_P^*. Even in the best situation for VIB, if $\lambda = 0$, both firms invest less than the first best. Because of the complementarities, the underinvestment of the supplier spills over to the producer, which sees his marginal return on investment falls. It does remain true that underinvestment will be more pronounced for the supplier than for the producer.

In the outsourcing arrangement, both firms' investments are increasing in θ. Even in the most advantageous situation, where investments are equally valuable outside the relationship ($\theta = 1$), firms will again invest less than in the first best situation. The appropriable quasi-rent is now the value of complementarities and noncooperative decision-making leads each party to only consider half of this value when deciding on its own investment. This lowers the denominator in (9) and results in a lower multiplier effect of the complementarities. If investments are entirely specific ($\theta = 0$), investments are only half as large as the firms now discount both the direct and indirect effects of their investments.

Comparing the two organizational forms, we find that with complementarities it becomes possible that the supplier's investment is larger under VIB than under O. This will be the case in the situation that is most favorable to integration, $\lambda = \theta = 0$, but ceases to hold if either λ or θ grows too large. Under the same assumptions, the producer's investment will be larger under integration than under outsourcing,[13] but this does not hold generally anymore with complementarities. If it is too easy for the producer to take control over the supplier's assets (λ is high), reduced investment by the supplier will lower the marginal return to the owner's investment through the complementarities. As a result, it is possible that the producer invests more under outsourcing. This is more likely to happen if investments are less specific (θ is high). At the extreme, if $\lambda = \theta = 1$, investments of both parties will be larger under outsourcing than integration and integration will never be desirable. In general, there exists a lower threshold $\underline{\lambda}$ for λ below which $x_P^{VIB} > x_P^O$ and an even more stringent lower threshold such that $x_S^{VIB} > x_S^O$. Both thresholds are declining in θ.

Proposition 1 *There exist $\underline{r}$, $\overline{r}$, and $\underline{\alpha_{PS}}$ such that if $\alpha_{PS} < \underline{\alpha_{PS}}$ the unique subgame perfect equilibrium ownership structure, z^*, is given as follows:*

$$\begin{aligned} z^* &= VIB \quad \text{for} \quad \alpha_P/\alpha_S > \overline{r}, \\ z^* &= O \quad \text{for} \quad \alpha_P/\alpha_S \in (\underline{r}, \overline{r}), \text{ and} \\ z^* &= VIF \quad \text{for} \quad \alpha_P/\alpha_S < \underline{r}. \end{aligned}$$

Moreover, $\partial\overline{r}/\partial\theta > 0$ and $\partial\underline{r}/\partial\theta < 0$; and $\partial\overline{r}/\partial\lambda > 0$ and $\partial\underline{r}/\partial\lambda < 0$.

[13] With $\lambda = \theta = 0$, it can only be the case that $x_P^{VIB} < x_P^O$ if $\alpha_P/\alpha_S < \alpha_{PS}/2$, but in such a situation VIF will be preferred over VIB, and the adjustment margin between VIB and O is irrelevant.

Taking the limit for α_{PS} going to zero, the proof boils down to the proof of Proposition 1 in Acemoglu et al. (2005).[14] Differentiating $\overline{r}$ and $\underline{r}$ establishes the comparative static results.[15]

The prediction from Proposition 1 is intuitive. When the direct marginal effect of investment by the supplier (α_S) is zero, the optimal ownership structure will be integration with the producer in control. If only investment by the producer matters, we want to give him optimal incentives. When α_S rises relative to α_P, the optimal ownership structure shifts at some point to outsourcing as the rising importance of the supplier's investment makes her underinvestment under VIB increasingly costly for the joint surplus production. Eventually, if α_S becomes sufficiently large it will even be optimal to put the supplier in control of the integrated firm. If investments are less specific and remain somewhat productive when used in isolation (high θ), the range for α_P/α_S where outsourcing is ideal expands. If it is easier for the owner of the integrated firm to appropriate the subsidiary's investments (high λ), outsourcing becomes more attractive because investment by the acquired firm declines further (the underinvestment problem under integration becomes worse).

Introducing complementarities (α_{PS}) complicates the analysis substantially because now each firm's marginal return on investment depends on the other firm's decision. While we cannot establish the impact on the likelihood of vertical integration in general, we can sign the effect in come cases. We discuss two predictions. First, Proposition 2 establishes that the equilibrium ownership structure from Proposition 1 does not hold anymore for sufficiently large complementarities. In such a case there exists a range of parameter values for λ and θ where outsourcing dominates integration even if one of the firm's investment has no direct impact on the joint surplus.

Proposition 2 *There exists $\overline{\alpha_{PS}}, \overline{\lambda}(\theta)$ such that if $\alpha_{PS} > \overline{\alpha_{PS}}$ and $\lambda > \overline{\lambda}$ the optimal ownership structure will be outsourcing even if $\alpha_S = 0$. Moreover, $\partial\overline{\lambda}/\partial\theta < 0$.*

Proof in Appendix.

Second, we show how the equilibrium ownership structure (as defined in Proposition 1) is changed at the margin when small complementarities are introduced. Given that the optimal investments under VIB are a decreased function of λ when complementarities are present, the effects again depend crucially on the level of λ. A lower λ worsens the outside option of the producer and raises supplier investment. In turn, this raises the marginal benefit of producer investment through complementarities, increasing the optimal x_P. Only if the θ and λ parameters are sufficiently low are we certain that the producer invests more under (backward) integration than under outsourcing. In other words, only if investments are sufficiently specific and sufficiently hard to appropriate can we unambiguously determine the effect on the optimal organizational structure.

Proposition 3 *There exist a $\underline{\lambda}$ and $\underline{\alpha_{PS}}$, such that if $\lambda < \underline{\lambda}$ and $\alpha_{PS} < \underline{\alpha_{PS}}$ the probability of outsourcing is negatively related to the size of complementarities. $\underline{\lambda}$ has the following properties:*

[14] For some parameter values $\underline{r} > \overline{r}$ and outsourcing will never be optimal. Given that we do observe a lot of outsourcing in the data, we follow AAGZ by limiting attention to the parameter space where this situation does not occur.

[15] Note that we have defined λ as one minus the same parameter in AAGZ.

- $\partial\underline{\lambda}/\partial\theta \leq 0$
- $\partial\underline{\lambda}/\partial\alpha_{PS} > 0$

The proof is in the Appendix, but the intuition is straightforward. If the loss that that the owner (under integration) incurs in the outside option relative to joint production is sufficiently large (λ sufficiently low), the existence of complementarities will make vertical integration more desirable. Complementarities increase the difference between the producer's payoff inside and outside the relationship, while they do not affect the outside option of the subsidiary (the supplier). In relative terms, complementarities worsen the outside option, hence the bargaining position, of the owner and they lessen the underinvestment problem of the subsidiary.

Consider the optimal investments when they are highly specific and impossible to confiscate ($\lambda = \theta = 0$) and complementarities are extremely low. Equations (8) and (9) predict that both $x_P^{VIB} > x_P^O$ and $x_S^{VIB} > x_S^O$. Introducing a small amount of complementarities will raise the joint production in proportion to $x_P x_S$, which will be larger under VIB than O. Complementarities raise the marginal product of both parties' investments more under VIB, because of higher counterpart investment, making VIB more advantageous. At the same time, differentiating the investments in (8) and (9) by α_{PS} reveals that the supplier investments under VIB are the most responsive of the four to complementarities. Hence, when α_{PS} grows larger, VIB becomes even more preferable, indicated in Proposition 3 by $\partial\underline{\lambda}/\partial\alpha_{PS} > 0$.

However, this mechanism only works if λ is sufficiently low. For higher λ's, the investments under VIB decline relative to O. In particular, if $\lambda > 0$ and/or $\theta > 0$, the producer investments immediately become less responsive to complementarities under VIB than under O. Eventually, for sufficiently large complementarities, even supplier investments become less responsive to complementarities under VIB than under O, making outsourcing more attractive, with the limit result illustrated in Proposition 2.

Finally, if the value of the investments outside the relationship is increased (higher θ), the threshold for λ below which complementarities favor integration declines, i.e. becomes more stringent. In this case, underinvestment is less of a problem under outsourcing and investments become more responsive to complementarities.

4 Empirical Model

The model yields a number of testable predictions on the relationship between outsourcing and investment intensities (α_P and α_S), complementarities (α_{PS}), and the specificity (θ) or appropriability (λ) of investments. In this section we describe how we map the theoretical concepts into observable variables and we describe the estimating equations.

The most important predictions relate investment intensities to outsourcing and several investment characteristics modify this relationship. In order to gauge the direct effects of our empirical measures of specificity, complementarities, and the cost-share on outsourcing, we first estimate the following equation without technological intensities:

$$OUTS_{fj} \quad = \quad \alpha_1 Specificity_{fj} + \alpha_2 Complement_{ij} + \alpha_3 Cost\text{-}share_{fj} + \text{Controls}_{fj} + \epsilon_{fj}. \tag{10}$$

The dependent variable is an indicator that takes on the value of one if input j, which is used as an input in any of the plants of firm f that produces output i, is not produced as an output by any of firm f's plants and zero otherwise.

The three variables of interest have straightforward predictions on the likelihood a firm outsources input j. If specificity is high, it will be harder or even impossible to purchase inputs on the spot market. If complementarities are positive, integration becomes more attractive, at least locally, as demonstrated in Proposition 3. If the cost-share is high, transaction cost considerations would suggest that it becomes more efficient to set up a customized governance system for input j, such as internalizing production. Property rights considerations predict integration if the marginal effects of the two firms' investments are sufficiently unbalanced. If the cost-share is high, imbalances will more quickly lead to integration and outsourcing becomes less likely. The data section introduces several proxies for specificity and discusses how the other variables are constructed.

The controls included in this and all following equations include the size and age of firm f, as well as industry averages for output i and input j. Every firm is associated with the industry of its core output i.[16] These variables control for the predictions in Stigler (1951) that outsourcing will increase as industries mature and grow in size.

Additional variables are included to control for technological explanations for a firm's outsourcing decision: productivity, composition of the workforce, and complexity of the product. More efficient firms are likely to have less of an incentive to outsource. A high share of non-production workers could indicate a reduced focus on production activities or more advanced production and lead to greater incentives to outsource non-core activities. Firms might be more reluctant or less able to outsource parts of a complex production process, which we proxy with the number of inputs required to produce the core output i.

A positive estimate on the α_1 coefficient in equation (10) would indicate that transactions that involve specific assets, for example due to customization, have *ceteris paribus* a greater chance of being vertically integrated. Next, we investigate whether the more nuanced predictions related to marginal investment incentives, which are unique to the property rights view of the firm, are supported.

In order to apply the model to the data, we add a random error ϵ^z to aggregate welfare. Backward vertical integration will be preferred over outsourcing if $\Delta W(\alpha, \lambda, \theta) \equiv W^{VIB}(\alpha, \lambda, \theta) - W^{O}(\alpha, \lambda, \theta) \geq \epsilon^{VIB} - \epsilon^{O}$. Assuming the errors are normally distributed, comparative statics for the ΔW entity can be investigated using a Probit model for the outsourcing indicator. The theory suggests that the effects are complicated and not monotone in most variables. The exercise is further

[16] Some of the specificity measures and controls vary only at the industry level, in which case the subscripts should be ij instead of fj.

complicated because integration can also be forward, i.e. if $W^{VIF}(\alpha,\lambda,\theta)-W^{O}(\alpha,\lambda,\theta)\geq\epsilon^{VIF}-\epsilon^{O}$, and there is no way to tell both forms of integration apart in the data.

At the very least, the impact of producer investments depends on the level of supplier investment. For example, limiting attention to the trade-off between backward vertical integration by the producer and outsourcing in the absence of complementarities, Proposition 1 predicts that the likelihood of integration is increasing in the ratio of the two firm's marginal investment impact on the joint surplus (α_P/α_S). This incorporates a crucial aspect of the property rights theory, that control is intrinsically indivisible: it strengthens incentives for the party that receives control, but weakens incentives for the party that loses it. The *relative* importance of both parties' investments will determine the optimal ownership structure.

Moreover, for an integrated firm it is impossible to know whether the producer owns the supplier or vice versa. All we observe is whether an input is produced internally or outsourced. At the margin, increases in technological intensity of suppliers and buyers still have opposite effects on the outsourcing decision, but this might not be apparent in a data set that combines a range of industries. An increase in (relative) technological intensity of a producer (α_P) will make it optimal to choose a governance structure that provides better incentives to the producer to reduce his underinvestment. It makes backward vertical integration more attractive than outsourcing, consistent with the evidence in AAGZ, but it also makes outsourcing more attractive than forward integration. The overall effect on the vertical integration-outsourcing trade-off is ambiguous. AAGZ cite previous studies to argue that only the former margin is relevant in manufacturing, but it seems unnecessarily restrictive to limit attention to this case.

To incorporate the possibility of both forms of integration, one has to allow for the impact of one firm's marginal investment intensity (II) to depend on the other firm's intensity. The simplest such specification is

$$OUTS_{fj} \;=\; \beta_P II_i^P+\beta_S II_j^S+\beta_{PS}\left(II_i^P-II_j^S\right)^2+\text{Controls}_{fj}+\varepsilon_{fj}. \qquad (11)$$

Restricting $\beta_{PS}=0$ in equation (11), reduces it to the estimating equation in AAGZ. We predict that $\beta_{PS}<0$, i.e. outsourcing is less likely if the two industries differ a lot in investment intensity.

According to this specification, the marginal impact of producer investment on outsourcing will be proportional to $\beta_P+2\beta_{PS}(II_i^P-II_j^S)$. If both industries are equally technology intensive, the PRT predicts that an outsourcing arrangement is likely. Starting from such a situation, raising the technological intensity of the producer should make (backward) vertical integration somewhat more likely. Hence we expect $\beta_P<0$, as in AAGZ.[17] If the relevant trade-off is between VIF and O, a similar increase in producer investment should make outsourcing more likely. This situation applies if II_j^S is much larger than II_i^P and the second term dominates the marginal effect of producer investment on outsourcing. It will be positive if $\beta_{PS}<0$. Similar reasoning for the supplier leads to the prediction that $\beta_S<0$, which differs from AAGZ as they assume that the only relevant

[17] Note that AAGZ use $1-OUTS_{fj}$ as dependent variable, inverting all signs compared to our specification.

margin in the data is between VIB and O.

A similar modeling approach would be to include the interaction of the two technological intensities, $\gamma_{PS}(II_i^P \times II_j^S)$, in equation (11) instead of the squared term.[18] In this specification, the marginal impact of producer investment on outsourcing will be proportional to $\beta_P + \gamma_{PS} II_j^S$. At low levels of technological intensity of the supplier—α_S close to zero in the theory and II_j^S close to zero in the data—the relevant margin will be between O and VIB. As before, theory predicts that producer investments will lead to integration and the effect of II_i^P on outsourcing is dominated by β_P, which is expected to be negative. On the other hand, at very high levels of II_j^S, the other margin (between O and VIF) will be the relevant one and the effect should be reversed. Raising II_i^P now makes outsourcing more likely, which will be reflected in a positive coefficient on the interaction term ($\gamma_{PS} > 0$), which now dominates the marginal effect.

The theoretical predictions are less clearcut if investments of producers and suppliers are complementary, i.e. if the joint surplus is increased when both investments are raised together. Proposition 3 indicates that the probability of outsourcing would be reduced, at least for moderate complementarities and for sufficiently low appropriability of investments. With complementarities, one would expect high levels of investments by both firms, as can be seen directly from equations (6). As a result, the presence of complementarities has the opposite effect on the coefficient of the interaction term (or the square term) than the standard PRT effect discussed above, making its sign ambiguous. The mechanism is that complementarities lower the outside option and hence the bargaining position of the controlling firm. Underinvestment of the subsidiary is diminished, which is extremely costly in the case of complementarities. As a result, investments by the two firms will be more similar than in the absence of complementarities, while at the same time the probability of outsourcing is reduced.

Given that we observe a variable that captures (technological) complementarities directly, we can estimate the augmented equation

$$\begin{aligned} OUTS_{fj} \quad = \quad & \beta_P II_i^P + \beta_S II_j^S + \beta_{PS}^0 \left(II_i^P - II_j^S\right)^2 \\ & + \beta_{PS}^1 Complement_{fj} \left(II_i^P - II_j^S\right)^2 + \text{Controls}_{fj} + \varepsilon_{fj}. \end{aligned} \tag{12}$$

If complementarities are entirely absent, the predictions of Proposition 1 apply and we expect $\beta_{PS}^0 < 0$. Complementarities introduce an opposing effect, according to the predictions of Proposition 3, and we expect $\beta_{PS}^1 > 0$.

We estimate the three equations (10), (11), and (12) using five alternative measures of technological intensity which are introduced in the next section: skill, innovation, R&D, technology use, and capital. These measures are likely to differ in appropriability, corresponding to the λ parameter in the theory. We have ordered them by increasing ease of appropriation, which should correspond

[18]The only difference would be that it omits the quadratic intensities, while their coefficients in equation (11) are restricted to be the negative of the interaction term coefficient. The flexible specification we introduce below nests both approaches.

to increasing attractiveness of outsourcing.

At the same time, other observable variables will influence the expected effects. Most notable is the degree of specificity and theoretical results in AAGZ demonstrate that the PRT predictions should be enhanced if the input makes up a larger share of the producer's costs. Moreover, results might be different for multi-plant and single-plant firms. In order to allow flexibly for all these effects, we estimate the following general specification:

$$\begin{aligned} OUTS_{fj} &= \sum_{k=0}^{2}\sum_{l=0}^{2-k}\beta_{fj}^{kl}(II_i^P)^k(II_j^S)^l + \text{Controls}_{fj} + \varepsilon_{fj} \qquad (13)\\ \text{with } \beta_{fj}^{kl} &= \beta_0^{kl} + \beta_{cs}^{kl}\mathit{Cost\text{-}share}_{fj} + \beta_{mp}^{kl}\mathit{Multi\text{-}plant}_f + \beta_{co}^{kl}\mathit{Complement}_{fj} \\ &\quad + \beta_{sp1}^{kl}\mathit{Rauch}_j + \beta_{sp2}^{kl}\log(\mathit{Producers}/\mathit{Suppliers})_{ij}^{COM}. \end{aligned}$$

This equation contains five technology intensity terms—two linear, two quadratic, and one interaction term—with a further 25 terms interacting the five technology terms with five variables (the last two capture specificity and will be discussed in the next section). Using the estimates of equation (13), we can evaluate the marginal effects of producer and supplier investments at various points—high or low complementarity, high or low specificity, etc.—to verify to what extent the results accord with the PRT predictions.

5 Data and Measurements

Outsourcing

The dependent variable in our analysis, the outsourcing dummy, is constructed using firm level data on commodity inputs and outputs. The Canadian Annual Survey of Manufacturers (ASM) collects detailed commodity information on input use and outputs using the six-digit level of Standard Classifications of Goods (SCG).[19] It is a plant level data set, but contains firm identifiers to link plants under common ownership. The commodity level input and output information is only collected for larger plants, which receive an extended survey questionnaire.[20] We use the 1988 and 1996 data.

The recorded input purchases include both within-firm transactions and transactions with independent suppliers. Because we cannot distinguish the two types of transactions, we capture outsourcing as a binary variable. If input j is purchased by any plant of firm f and none of its Canadian plants list it as an output, we consider this input outsourced. If we observe positive output of commodity j at any of the firm's plants, we assume that the firm satisfies its entire input

[19] The ASM is the Canadian equivalent of the Longitudinal Research Database maintained by the U.S. Census. It is a five-yearly census of all manufacturing establishments, with all large plants and a sample of smaller plants interviewed annually.

[20] Approximately half of all plants, accounting for 85% of shipments, receive the long-form questionnaire.

demand for j internally and we set the outsourcing dummy equal to zero.[21]

$$OUTS_{fj} = \begin{cases} 0 & \text{if input } j \text{ is produced by at least one of the plants owned by firm } f \\ 1 & \text{if input } j \text{ is not produced by any of the plants owned by firm } f \end{cases}$$

Each 'firm-input commodity' combination fj (producer-supplier) constitutes a separate observation in our analysis.[22,23] The total number of observations is the product of the the average number of inputs and the total number of firms. The cost-share for this observation is calculated as a the share of input j in total commodity inputs purchased by firm f (across all its Canadian plants).

Technological intensity

The model relates the probability of outsourcing to (a) the relative importance of producer and supplier investments, and (b) characteristics of these investments, such as their specificity, complementarity, and ease of appropriation. The theory provides predictions how outsourcing is expected to vary with investment intensity, but does not specify the nature of the investments. For example, AAGZ note that the investment must "require tacit knowledge or human capital", so that "decision rights over these investments cannot be transferred between the two parties". Their preferred measure is R&D intensity, expenditures divided by value added, constructed at the industry level. Physical capital intensity (again divided by value added and at the industry level), which is less skewed both within and between industries, is used as a robustness check.

We use two comparable measures, R&D and capital intensity, and create three additional measures of technological intensity: skill intensity, innovativeness, and technology use. The different investment intensities will be denoted by $II_{R\&D}$, $II_{K/L}$, II_{skill}, II_{innov}, and II_{tech}. While these measures do not necessarily represent specific investments in their own right, they are likely to be associated with and accompanied by other (unobservable) investments which are specific.

Skill intensity is constructed as the fraction of employees in an industry, weighted by hours worked, that attained some post-secondary education, including university degrees. Capital intensity is defined as the logarithm of the capital stock per hour worked.[24]

[21] An alternative assumption would be to consider input j as outsourced if the firm's input requirements of j exceeds its recorded output (across all its plants). In the vast majority of cases, both approaches give the same result.

[22] The definition of our dependent variable is similar to the one used by AAGZ, except that they construct a vertical integration measure—the inverse of our outsourcing measure—using the U.K. input-output table at the industry level. For each industry in which a firm has an active plant, the input-output table lists the set of input industries where the firm might consider vertically integrating. If the firm owns a plant in one of these input industries, the integration dummy is coded as one. Otherwise, the input is considered outsourced. Because the set of potential input industries is large (all industries with positive values in the input-output table), outsourcing is extremely common in AAGZ: the average of $OUTS_{jf}$ is 0.99 against 0.92 for us.

[23] Hortaçsu and Syverson (2006) construct an integration dummy using the U.S. input-output table. This table is more detailed than that of the U.K. and they only consider ownership in industries that provide at least 5% of the inputs (backward) or purchase at least 5% of the output (forward).

[24] The education and hours worked information is available at the L-level of Input-Output industries (167 industries). Capital stock data are only available at a slightly less disaggregate level (R-level or 123 industries), requiring some

The measures of industry R&D, innovativeness, and technology adoption are constructed from information collected through the 1993 Survey of the Innovation and Advanced Technology Survey, conducted by Statistics Canada for a representative sample of larger plants. No quantitative information on investments is available, but it contains rich information on the frequency that manufacturing plants engage in a variety of innovative activities. Detailed information on the survey is in Baldwin and Hanel (2003).

Our measure for R&D intensity is the average frequency that plants report to engage in R&D on an ongoing basis. The innovation intensity measures the frequency that product or process innovations are introduced during the survey period. Technology use is measured as the average number of advanced technologies (from a list of 26) in use by manufacturing plants in an industry.

All five technology variables are constructed at the industry level. One advantage over firm level measures is that they average over firms with different integration strategies, providing an average characterization of the technological intensity of each industry (as pointed out by AAGZ). As a robustness check, we can limit the analysis to outsourcing information in 1996, while the technological intensities are constructed in 1993, further reducing the influence of the vertical organization on the observed investment intensities.

The industry level technology measures are mapped into the 'firm-input commodity' observations as follows. The producer investment intensity is the intensity for the industry of the firm's major line of business, its core product i. The supplier intensity is determined by mapping the commodity inputs at the SCG classification into the industry classification using appropriate concordance tables (we denote the supplier's industry by j as well).[25]

Table 1 shows the correlation between the different measures of technological intensity. These variables are clearly picking up different things. The highest correlation is 0.56, between the number of technologies in use and the likelihood of innovative activities. The capital intensity measure has particularly low correlations with the frequency of R&D, only 0.06, or innovation, 0.20. The skill intensity measure that proxies for human capital, on the other hand, has relatively high (but by no means perfect) correlations with each of the four other measures: each of its correlations is between 0.30 and 0.44. The large degree of variation suggests that these different measures could have a rather different relationship to the degree of specificity in the producer-supplier relationship.[26]

$\Rightarrow$ [Table 1 approximately here] $\Leftarrow$

Investment characteristics: specificity, complementarity, appropriability

The theory assumes that the value created in the producer-supplier relationship is increased when specific investments are made. We observe a number of variables that plausibly proxy for the level

aggregation of the working hours to construct the capital-labor ratio.

[25] All data are confidential Statistics Canada information and have to be used on-site in Ottawa. We draw on internal Statistics Canada concordance tables to map commodities into industries and to aggregate industries.

[26] These industry measures come from surveys other then the ASM and for some industries the data are missing.

of specificity and hence indicate when the theory should apply. These measures can be thought of as determinants of θ in the model. In the limit, for $\theta \rightarrow 1$ investments are entirely unspecific and outsourcing will always be optimal.

We observe at the commodity level whether the input is a differentiated product, according to the index by Rauch (1999), which is likely to increase the probability that a successful supply relationship entails specific investments. The indicator ($Rauch_j$) takes on a value of zero if a product is traded on a listed exchange or if prices are quoted in trade publications, and one otherwise. A second variable that will increase the specificity of investments is the fraction of Canadian production the input demand of the producer constitutes ($fraction_{fj}$). If this is large, outsourcing can be a risky strategy as alternative sources of supply (or demand) can be hard to find in the short run. The loss in surplus when a relationship breaks down and a firm has to turn to its outside option is likely to be related to the relative number of producers and suppliers in the industry. The number of firms proxies for the outside options of the contracting parties and we can calculate them at the industry ($Producers_i^{IND}$ and $Suppliers_j^{IND}$) or at the commodity level ($Producers_i^{COM}$ and $Suppliers_j^{COM}$).

An important technological dimension of the producer-supplier relationship can be captured by an index of production complementarity. We define a variable $Complement_{ij}$ to capture the overlap in the set of input commodities needed to produce the core output i of firm f and the input j. If the overlap is large, it is more likely that investments made by the producer of j (the supplier) will have spillover effects on the investments of the producer of i and vice versa. This is expected to capture the effect of the α_{PS} parameter in the model.

The variable is constructed as follows. The most detailed Input-Output table gives for each of 243 industries the input requirements in terms of 476 input commodities. For each input commodity j and core output i, we know the producing industry and hence the set of required input commodities. Let N^i be the set of all inputs needed to produce output i, and $N^{j,i}$ be the set of inputs that are used both in the production of input j and the core output. The production complementarity, $Complement_{ij}$, is defined as $N^{j,i}/N^i$. It ranges from zero, if none of the inputs used in the production of input j are usable in the production of output i, to unity, if all of output i's inputs are also used in the production of input j.

Finally, we do not have a separate variable to proxy for the ease with which investments can be appropriated in the case of a breakdown of the relationship. However, the five technological intensity measures surely differ in this respect. At one extreme, it should be relatively easy to appropriate, i.e. the reduction in surplus should be modest, if the owner takes control of the physical capital investments of the subsidiary. At the other extreme, the human capital in the skill intensity measure is likely to be accompanied with investments in tacit knowledge that are nearly impossible to appropriate. The three innovation intensities are expected to be intermediate, with investments associated with technology use easier to appropriate than investments associated with R&D or other innovative activities.

Summary statistics

A number of other variables are included in the regressions to control for idiosyncratic firm differences. These include characteristics of the producer's production process: the share of non-production workers in the workforce, the total number of inputs used to produce the firm's core output i (a measure of complexity of the product), and labor productivity (value added per worker). Other producer controls include the age of the firm (time since start-up for the oldest plant) and size (log employment over all plants).[27] We also include the average of the last two variables for the producer and supplier industries, averaging across all plants in the industry.

Summary statistics for all variables are in Table A.1 in the Appendix. There are 6,199 firms in 1988 and 7,111 firms in 1996; we treat the data as a cross-section. On average these firms use 4.69 commodity inputs. Limiting the sample to observations with nonmissing data for all controls gives us 50,179 firm-input observations. The simple average of $OUTS_{fj}$ is 0.919; indicating that the proportion of inputs that are outsourced is quite high. The weighted average of $OUTS_{fj}$, using input value weights, is lower as firms are more likely to internalize inputs that constitute larger shares of costs. The mean value of $Complement_{ij}$ is 0.554 which means that on average 55 percent of inputs used in production of the core output are potentially used in the production of the input. The average $Rauch_j$ index is 0.418—42 percent of inputs are classified as differentiated inputs. A pattern worth noting is that the average technology intensities are very similar for producer and supplier industries.

6 Results

Impact of specificity and complementarities on outsourcing

Before turning to the predictions of the PRT model, we first present estimation results for equation (10) to gauge the direct impact of specificity and complementarity on the outsourcing decision. The results in Table 2 also illustrate the importance and direction of the effect of the control variables, which will be included in all subsequent regression.

$\Rightarrow$ [Table 2 approximately here] $\Leftarrow$

A first set of controls, age and size, capture market size effects, as discussed in Stigler (1951). They are significant predictors of outsourcing, but the direction of the effect is not always straightforward even though the results tend to be robust across the different columns of Table 2. Stigler's hypothesis is that the degree of specialization, hence the opportunity for outsourcing, is limited by the size of the market. When industries mature and grow in size, firms are expected to be more prone to outsource. The estimates indicate that industries with older firms tend to outsource less, but that within those industries firms that are older than the industry average outsource

[27] We use these controls in deviations from industry medians in order to remove industry-specific effects that could be correlated with the industry level explanatory variables of interest.

more. Somewhat counterintuitively, the average age in the supplier industry is also associated with reduced outsourcing, but the effect is often insignificant. The average firm size in producer industries has no pronounced effect on outsourcing, but the largest firms do more in-house. Firm size in the supplier industry, on the other hand, is positively and strongly associated with increased outsourcing. Obviously, these are merely correlations and reverse causality clearly plays a role.

The next set of indicators captures technological explanations for outsourcing. The firm's productivity has an insignificant effect. On the one hand, highly productivity plants have an incentive to take on more production tasks to leverage this advantage more widely or protect their know-how by outsourcing less. On the other hand, firms that outsource many tasks might improve their productivity as they specialize. The same two-handed reasoning also applies to the share of non-production (skilled) workers, which has a negative, but insignificant effect on outsourcing. As these workers are expected to be involved in production of knowledge-based assets, protection of know-how will be more important. Their skills might also be related to the specificity of investments in human capital, which is discussed in greater detail below.[28] The number of inputs that enter a firm's core output ('complexity') is, as expected, a negative and significant predictor of outsourcing. It mirrors a finding in Van Biesebroeck (2006) where automobile assembly plants that produce a larger variety of final outputs, requiring more inputs, bring more of the assembly tasks in-house.

Our measure of technological complementarity between input j and core output i—the fraction of inputs in i which are also used to produce j—is strongly negatively related to the likelihood of outsourcing. Inputs that share intermediates with the core output are much more likely to be produced in-house. In addition, the likelihood of outsourcing an input is decreasing in its cost-share, consistent with the model in AAGZ. Both of these effects are highly significant and very large in economic terms: a one standard deviation increase in complementarity lowers the probability of outsourcing by 36% and a similar increase in the cost share lowers it by 23%.

We now turn to the variables that proxy for the specificity of the transaction. Columns (2)–(7) of Table 2 report the estimates for various indicators, each indicating that greater specificity is associated with a reduced probability of outsourcing. The negative coefficient on the *Rauch* indicator, in column (2), confirms our prior that outsourcing is less likely for differentiated inputs, for example because of customization. Intuitively, this objective measure of differentiation should be a necessary condition for specificity to be relevant. The probability of outsourcing is also reduced if the input demand of firm f represents a higher fraction of total Canadian production of good j, in column (3). A high value is likely to make it more difficult to find alternative sources of supply or new clients and outsourcing will be associated with poor outside options for both firms involved in the transaction.

Next, we look at the number of producers or suppliers to proxy for the thickness of the market—again related to the outside option of each side to the transaction. Results in column (4) are for numbers of users and producers of commodity j, the producers and suppliers in the model. Results

[28] At the industry level, productivity is negatively and the fraction of non-production workers positively related to outsourcing.

in column (5) are comparable, but rely on firm-counts at the industry level as a robustness check.[29] These measures only have an unambiguous relation to outsourcing if only one type of integration (backward or forward) is possible or dominant in the data. The estimates, positive for number of producers and negative for suppliers, are consistent with the relevant margin being $VIB - O$ and highlight the importance of the number of suppliers in particular, consistent with results in AAGZ. If there are more producers, the outside option of the supplier is strengthened, making outsourcing a more attractive option. With more suppliers, the expected effects and estimated signs are reversed. The effects are particularly large if the number of firms is measured at the commodity level. We can combine the opposite effects of the suppliers and producers by including the (log) ratio, results in columns (6) and (7). This produces a highly significant coefficient estimate, with the sign again consistent with the $VIB - O$ trade-off.

As the signs on the numbers of firms should go in the opposite direction if the relevant trade-off was $VIF - O$, the results are only consistent with the PRT predictions if backward integration is more likely. It is possible to obtain results consistent with both types of integration if we introduce a third term: the interaction of the numbers of suppliers and producers. If the number of suppliers is small, the effect of the number of producers on the likelihood of outsourcing will be dominated by the uninteracted producer variable, while the sign on the interaction term will dominate if the number of suppliers is large. At the same time, if the number of suppliers is small, the relevant trade-off is more likely to be $VIB - O$ as producer underinvestment under VIF will not be remedied by outsourcing. Putting these two tendencies together, PRT considerations predict a positive coefficient on the uninteracted number of producers and a negative coefficient on the supplier-producer interaction, which is exactly what we find in columns (8), at the commodity level, and (9), at the industry level. If there are a large number of suppliers it is more likely that $VIF - O$ is the relevant margin and the dominance of the negative interaction coefficient in this case again confirms with the PRT prediction.[30] Similar reasoning should lead to a positive sign on the number of suppliers as well, which is what we find at the industry level (column (9)), but not at the commodity level (column (8)).

Evidence on the PRT allowing for complementarities

The top panel of Table 3 contains the probit coefficient estimates on the two variables of interest in equation (11), the importance of producer (β_P) and supplier (β_S) investment intensities, excluding at first the squared difference term. The dependent variable throughout is the outsourcing dummy. Each of the five columns uses a different measures of technological intensity. With the exception of the last column, the results are in line with the findings in AAGZ—which uses R&D intensity, corresponding to the results in column (3). The same controls as in Table 1 are included, except

[29] While these measures are related to specificity through the impact on outside options, they will also capture market power effects, which can lead to spurious correlation with vertical integration.

[30] This approach is reminiscent of the reasoning behind including the interaction or squared difference term in equation (11). Including $(\log(\#\text{ of producers}) - \log(\#\text{ of suppliers}))^2$ in the regression, we find a positive and significant coefficient for both the commodity and industry level measures, again consistent with the PRT predictions.

for the industry level age and size, but not reported.[31] As before, the cost-share and technological complementarity are strongly and negatively related to the probability of outsourcing.

⇒ [Table 3 approximately here] ⇐

Most importantly, the investment intensities of producers and suppliers have opposite effects on the probability of outsourcing: negative for producers and positive for suppliers. This pattern is consistent with the trade-off between backward vertical integration and outsourcing, as noted in AAGZ. If producer investments are more important, firms have an incentive to give control to the producer and bring the production of intermediates in-house. This strengthens producer incentives and reduces their underinvestment. Greater importance of supplier investments makes backward vertical integration, which gives low incentives to suppliers, less desirable.[32]

The pattern is the same for each of the four technology measures in columns (1)–(4) and all estimates are significant at the 1%. The coefficients are estimated notable larger for supplier investment intensities. Only when technological intensity is measured by the capital-labor ratio become the results insignificant for producer investments and negative for supplier investment.[33] Of the five measures, physical capital is arguably the least likely to be associated with asset specificity and the risk of hold-up. Much of the capital stock is likely to be easily redeployable in other uses, e.g. buildings and IT equipment, or equipment can be sufficiently flexible to be useful in many relationships. It is intuitive that the results are strongest for skills, innovation, and R&D as these activities are more likely to be specific and require tacit non-transferable knowledge.

The results provide support for the PRT model if the relevant empirical margin is between backward vertical integration and outsourcing and complementarities are low. As discussed earlier, if both modes of integration are relevant, the signs of the coefficients are ambiguous, as the marginal effect of either firm's technological intensity on outsourcing depends on the partner firm's technological intensity. We can allow for forward vertical integration and still have unambiguous predictions by including the squared difference in investment intensities in equation (11). The difference is predicted to be negatively related to the probability of outsourcing.

Results for the augmented equation, in the middle panel of Table 3, consistently reveals the opposite effect. The coefficient on the squared difference term is estimated positively in each column. Moreover, all coefficients are estimated precisely, with t-statistics ranging from 2.51 to 3.86. Trading relationships between firms in industries of vastly different technological intensity are found to be more likely to be organized as outsourcing relationships than occurring within integrated firms. The PRT suggests that it would be optimal in such a situation to integrate the firm and give the owner optimal investment incentives.

[31]The signs of the control variables are extremely robust across specifications and full results are available upon request.

[32]As in AAGZ, we find that the effects of both technology variables are strengthened if the input has a higher cost-share.

[33]The results in column (5) for the capital-labor ratio were also the most sensitive to the inclusion or omission of some of the firm or industry controls.

Including the interaction between the investments of the producer and supplier in equation (11) instead of the difference leads to the same finding. The coefficient on the interaction term is always estimated negative, opposite of the PRT prediction without complementarities (Proposition 1). It suggests a negative effect of each firm's investment on outsourcing when the other firm's investment is large. In contrast, the PRT predicts outsourcing to be more desirable if both firms make large investments. Complementarities are often modeled as a positive coefficient on the investment interactions in the objective function, as we did in the joint surplus function (1). Proposition 3 predicts complementarities to lead to integration, consistent with the negative estimates on the interaction term. The coefficient estimates suggest that the beneficial effect of complementarities on the investment incentives of the subsidiary can dominate the negative incentive effect that the PRT focuses on.

If producing the input and the final good requires many of the same processes and inputs, technological complementarities can dominated the optimal organization of the transaction. This changes the tradeoff between outsourcing and integration. Even if the user and supplier industry have to make similarly-sized investments, and the squared-difference term is low, integration can be attractive because of spillovers between the production process of the final good and the input. Such similarly-sized investments are especially likely when complementarities are high and the production processes are similar.

Estimation results for equation (12), in the bottom panel of Table 3, confirm the prediction. It turns out that the positive sign on the difference term in the middle panel is driven by high complementary transactions. In contrast, a large difference in investment intensity is predicted to lower the probability of outsourcing if complementarities are sufficiently low. How low they have to be differs by technology measure. For the capital, skill, and R&D measures the effect turns negative if technological complementarities are between 1.27 and 1.43 standard deviations below the average. For technology use and innovation intensity, complementarities of 0.85 standard deviation below the mean are sufficiently low to predict a negative coefficient on the difference term, as predicted by the PRT (Proposition 1).

An alternative explanation for the opposite findings in the middle panel of Table 3 is that the investment intensities are only imperfect proxies and many transactions in the sample do not require specific investments. Comparative advantage considerations suggest that high-tech industries are more likely to outsource low-tech intermediates and vice versa—consistent with the positive coefficients on the investment difference term. The PRT model is only expected to be relevant for investments that are truly relationship-specific. We explore the importance of specificity further below.

Two robustness checks confirm the main finding of Table 3. Table A.2(a) in the Appendix reports estimates of equation (12) only for multiplant firms, where the outsourcing variable can be measured more accurately. Results limited to the 1996 observations, where reverse causation between the 1993 technology intensity measures and the outsourcing dummy is diminished, are in Table A.2(b). In both cases, the results are very similar, although fewer coefficients are statistically significant in the smaller samples. Asymmetric investment intensities between producers and suppliers are associated with integration if complementarities are low, as predicted by the PRT. The relation reverses for high levels of complementarity, making integration more likely if investment intensities are similar.

Further evidence: complementarities, specificity, and appropriability

To account more generally for the relative investment intensities, complementarities, the strength of the relationship, and specificity of the transaction or investments, we also estimate the flexible specification in equation (13). Five linear, quadratic, and interaction terms of the technological intensities are included, with the coefficients on each term varying with five observable proxies. The full set of coefficient estimates is reported in Table A.3 in the Appendix. To illustrate the results more clearly, we evaluate the marginal effects of producer and supplier investment intensity on the likelihood of outsourcing at different points in the data. First, in Figure 1, we evaluate the effects at low complementarities (one standard deviation below the mean) and average values for all other variables.

$\Rightarrow$ [Figure 1 approximately here] $\Leftarrow$

The marginal effects of investments are plotted on the vertical axis. The horizontal axis represents the (log) difference in producer minus supplier intensity, both relative to their sample means, which played a crucial role in Proposition 1. A value of one indicates that the producer intensity is one standard deviation higher relative to the average producer intensity than the supplier intensity is relative to its average intensity. This can mean, for example, that the producer has an investment intensity one standard deviation above the mean, while the supplier has average intensity. The same x-value can represent a transaction with a producer with average investments and suppliers with investments one standard deviation below the average, etc. We use frequency weights from the sample to construct a weighted average for transactions with the same x-value.

Results for the full sample, on the left in Figure 1, illustrate that the PRT predictions are strongly supported for skill intensity and also hold for innovation, but less strongly for high relative supplier intensities—low x-values. The marginal impact of producer investments (blue, dashed lines) is to reduce the probability of outsourcing where producer investments dominate, for high x-values, but make outsourcing more likely for low x-values. Results for supplier investments (green, solid lines) are opposite on both sides of the spectrum. This corresponds to the predictions of Proposition 1. On the right, the relevant margin is between backward vertical integration and outsourcing. A further increase in the importance of producer investment makes integration more attractive as it gives the producer optimal incentives. At the opposite side of the x-spectrum, when supplier investments dominate, a similar increase in producer intensity now favors outsourcing over forward vertical integration.

For technology use and R&D, the PRT predictions are still supported for high relative producer intensity, but at high relative supplier intensity marginal effects of either firm's investments have no impact on outsourcing. As AAGZ argue that forward integration is rare in manufacturing, this could lead to limited explanatory power for the $VIF-O$ margin. For capital intensity, the results are still in line with the predictions for producer investment: it (weakly) decreases outsourcing on the right and increases outsourcing on the left. The impact of supplier investments, however, follows the same downward-sloping pattern, which is opposite of the PRT predictions. The supplier results for capital are highly insignificant though.

The results become even more supportive if the sample is limited to multiplant firms, on the right in Figure 1. The effects at low x-values, high relative supplier intensity, are now notably different from zero for innovation and R&D as well and even for technology use is the marginal effect of producer investment slightly positive. As can be seen from the vertical scales, the magnitudes of the marginal effects tend to be two to four times larger for multiplant firms.

In the following three figures, we focus on the effects of three crucial parameters in the model. First, in Figure 2, we vary the level of complementarities (α_{PS}) which are proxied by the *Complement* variable that measures the overlap in inputs between the two contracting firms. Second, in Figure 3, we vary the specificity of the transaction (θ) using two of the variables that were shown to predict outsourcing in Table 1: *Rauch* and the ratio of $Producers_i$ to $Suppliers_j$. Third, in Figure 4, we compare the marginal effects for the five technology intensities as the different investments have a natural ordering in terms of appropriability (λ).

Figure 2 illustrates the effects of varying levels of complementarities in the case of skill intensity. Results for the other innovative measures are qualitatively similar, but the differences tend to be less pronounced. The solid lines repeat the low complementarity patterns already shown in Figure 1. The effects for producers are now shown in black and for suppliers in grey. The dashed lines represents marginal investment effects for average levels of complementarities and the dotted lines are for high complementarities (mean plus one standard deviation).

For medium and, especially, for high levels of complementarities the marginal effects of investments change signs everywhere. The effect of higher producer investments on outsourcing quickly turn positive on the right, where we expect the relevant margin to be between backward vertical integration and outsourcing.[34] As Proposition 2 demonstrates, complementarities can explain such an effect, at least if the ease of appropriation of the investments is sufficiently high and investments are not too specific. Greater importance of producer investment can lead to outsourcing because it increases the cost of supplier underinvestment in the presence of complementarities. Further complementarities strengthen this effect, but unexpectedly, the results indicate that it also leads to increased integration if supplier investment rises.[35] Results for the $VIF-O$ tradeoff are the mirror image. At least for supplier investments, with medium or high complementarities the positive effect on the outsourcing probability on the left is more pronounced than the negative effect on the right, which is intuitive.

[34]By construction, the marginal effects eventually turn to zero at the extremes because the derivative of equation (13) is multiplied by the normal density function to construct the marginal effects.

[35]Proposition 2 is not informative here as it only applies to low levels of complementarities.

⇒ [Figure 2 approximately here] ⇐

Clearly, the degree of specificity will also influence the effect of investments on outsourcing. In Figure 3 we plot the marginal effects again for skill intensity, evaluating the variables that proxy for specificity at high and low values. The short-dashed lines are for transactions that involve homogenous products according to the *Rauch* measure, which are likely to be less specific. The long-dashed lines are for differentiated product transactions where there are far more suppliers than producers and the solid lines represent similar situations but with relatively more producers. As before, producer marginal effects are in black and supplier's in grey. The results are extremely similar for innovation and similar but less pronounced for R&D and technology use.

⇒ [Figure 3 approximately here] ⇐

The Rauch measure that captures product differentiation reinforces the effects in line with the predictions. The short-dashed lines are almost uniformly closer to the zero line, indicating that investments are much less informative for the outsourcing patterns of homogenous goods. The marginal effects for differentiated goods are particularly more pronounced for supplier investments.

The effects of a high (relative) number of producers are less obvious, but the results are again supportive of the PRT predictions. For low x-values where the tradeoff is between VIF and O, we expect stronger results for the long-dashed lines. If there are relatively more suppliers and fewer producers, the outside option of the producer (which underinvests under VIF) is strengthened. On the left in Figure 3, the two solid black line are closer to the zero-line than the long-dashed lines, in line with the predictions. Producer investments are less likely to lead to outsourcing if there are many of them. From the suppliers' perspective, a similar increase in their relative numbers strengthens the positive impact of their investments on integration (VIF) because they have weak outside options in outsourcing in this case.

Similar effects apply in reverse on the right where backward integration is more relevant, but only at extremely high x-values. Only at the extreme right is the negative effect of producer investment on the likelihood of outsourcing boosted by the presence of many producers. Similarly, the existence of few suppliers reinforces the positive effect of supplier investment on outsourcing, but only at the extreme right.

The final important parameter in the model (λ) is the ease with which the owner of the integrated firm can appropriate the subsidiary's investment should bargaining break down. The results in Proposition 2 indicate that high λ makes it more likely that complementarities will overturn the benchmark PRT predictions. At the extreme, if λ is one integration becomes highly unattractive as subsidiaries stop investing altogether. The different investment measures are likely to differ in appropriability. A priori, we would expect the order of increasing ease of appropriation to be as follows: skill, innovation, R&D, technology use, capital. Investments that require human capital are likely to be most difficult to appropriate (be highly "complementarity" in the Hart and Moore (1990) terminology). Innovation is likely to entail more tacit knowledge than R&D and the use of advanced technologies is similarly expected to incorporate more tacit knowledge than general capital equipment.

⇒ [Figure 4 approximately here] ⇐

The magnitude of the marginal effects in Figure 4 follows the same ordering. The effects for skill and innovation are drawn on a separate graph (at the bottom) because the effects are an order of magnitude larger. The shape of the marginal investment incentives for these two measures is also most in line with the PRT predictions. For the other three measures, the effects are smaller, especially for supplier investments. Interestingly, the evidence in AAGZ which we confirmed for our data in the top panel of Table 3, suggests that integration is more likely to put the producer in control. In the range where supplier investments dominate, at low x-values, the most pronounced effects are for producer investments which reduce the probability of integration. It suggests that integration is particularly damaging for the subsidiary's incentives for these measures.

7 Conclusions

Our findings are fourfold:

- Augmenting the property rights model with complementarities is able to generate a rich set of theoretical predictions. First, it can destroy the usual PRT tendency for integration if investment intensities are sufficiently asymmetric. Second, low amounts of complementarities will, all else equal, lead to more integration.
- Plausible proxies for specificity have predictive power for the ownership structure in Canadian manufacturing. Transactions are more likely to take place in an integrated firm if the inputs are differentiated, the production process is more complex, the producer purchases a large fraction of total Canadian production of the input, and the outside options of the two firms are low or very asymmetric. These correlations are in line with TCE and PRT. Without specificity of investments—acquiring relationship-specific assets or customizing the input—there would be no reason to vertically integrate.
- At low levels of complementarities, the PRT predictions are strongly supported: large asymmetries in investments lead to integration. The marginal effect of producer investments is to make integration more likely when producer investments dominate and outsourcing more likely when supplier investments are relatively more important. Effects for supplier investments are exactly the opposite, in line with the theory.
- By and large, the effects of complementarities, specificity, and appropriability on the marginal impact of investments are in line with the theoretical predictions. The existence of complementarities, proxied by the overlap in the input set of producers and suppliers, destroys the previous prediction. High specificity and low appropriability enhance the PRT predictions, both making integration optimal for less pronounced investment asymmetries.

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Appendix

Proof of Proposition 2

We only discuss the trade-off between backward vertical integration and outsourcing. As the problem is entirely symmetric for producers and suppliers, the trade-off between forward vertical integration and outsourcing is entirely similar.

The optimal investments, in equations (8) and (9), can be substituted in the aggregate welfare function to obtain the joint value that the two firms attain in either mode of organization. We assume – as in Whinston (2003) or AAGZ – that the choice of organizational form prior to the investment decisions, is accompanied by transfers, such that firms will always decide on the organization that maximizes joint surplus.

In each organizational form, aggregate welfare is given by the joint surplus generated within the relationship, i.e. on the equilibrium path, given by equation (1), minus the costs of both firms, equations (2):

$$W^z(\alpha,\lambda,\theta) \;=\; \alpha_P x_P^z + \alpha_S x_S^z + \alpha_{PS} x_P^z x_S^z - \frac{1}{2}(x_P^z)^2 - \frac{1}{2}(x_S^z)^2, \tag{14}$$

with x_P^z and x_S^z ($z \in \{VIB, O\}$) given by equations (8) and (9).

The threshold between the VIB and O organizational forms is characterized by $\Delta W = W^{VIB} - W^O = 0$. We look at the comparative statics in ΔW to see how this threshold changes with the importance of the producer's investment in the special case where $\alpha_S = 0$ (the most advantageous for the VIB organizational form):

$$\begin{aligned} \frac{\partial \Delta W}{\partial \alpha_P} \;=\;& x_P^{VIB} + (\alpha_P + \alpha_{PS} x_S^{VIB} - x_P^{VIB})\frac{\partial x_P^{VIB}}{\partial \alpha_P} + (\alpha_{PS} x_P^{VIB} - x_S^{VIB})\frac{\partial x_S^{VIB}}{\partial \alpha_P} + \\ & - x_P^O - \;(\alpha_P + \alpha_{PS} x_S^O - x_P^O)\frac{\partial x_P^O}{\partial \alpha_P} \;-\; (\alpha_{PS} x_P^O - x_S^O)\frac{\partial x_S^O}{\partial \alpha_P} \end{aligned}$$

To evaluate this expression we substitute the optimal investment policies, which in the case of $\alpha_S = 0$ simplify to:

$$\begin{aligned} x_P^{VIB} = \alpha_P / D^{VIB} \quad &\text{and} \quad x_S^{VIB} = \tfrac{1-\lambda}{2}\alpha_{PS} x_P^{VIB} \\ x_P^O = \tfrac{1+\theta}{2}\alpha_P / D^O \quad &\text{and} \quad x_S^O = \tfrac{1}{2}\alpha_{PS} x_P^O, \end{aligned}$$

with $D^{VIB} = 1 - \frac{1-\lambda^2}{4}\alpha_{PS}^2$ and $D^O = 1 - \frac{1}{4}\alpha_{PS}^2$. The partial derivatives of the investments with respect to α_P boil down to

$$\begin{aligned} \frac{\partial x_P^{VIB}}{\partial \alpha_P} = 1/D^{VIB} \quad &\text{and} \quad \frac{\partial x_S^{VIB}}{\partial \alpha_P} = \tfrac{1-\lambda}{2}\alpha_{PS}/D^{VIB} \\ \frac{\partial x_P^O}{\partial \alpha_P} = \tfrac{1+\theta}{2}/D^O \quad &\text{and} \quad \frac{\partial x_S^O}{\partial \alpha_P} = \tfrac{1+\theta}{4}\alpha_{PS}/D^O. \end{aligned}$$

Substituting all of this in the above expression gives

$$\frac{\partial \Delta W}{\partial \alpha_P} \;=\; \frac{\alpha_P}{(D^{VIB})^2}\left[1 + \left(\tfrac{1-\lambda}{2}\right)^2 \alpha_{PS}^2\right] \;-\; \frac{\alpha_P}{(D^O)^2}\left[\tfrac{(1+\theta)(3-\theta)}{4} + \tfrac{3(1+\theta)^2}{16}\alpha_{PS}^2\right]$$

If we take the limit for this expression for $\alpha_{PS} \to 1$, i.e. maximum complementarities, we find that

$$\left.\frac{\partial \Delta W}{\partial \alpha_P}\right|_{\alpha_{PS}\to 1} = \alpha_P \left[\frac{5-2\lambda+\lambda^2}{((3+\lambda^2)/2)^2} - \frac{(1+\theta)(15-\theta)}{9}\right] < 0 \quad \begin{cases} \text{if } \lambda > 0.45 \\ \text{or if } \lambda = \theta > 0.21, \end{cases}$$

in which case VIB will never be optimal. There is thus a threshold for λ above which outsourcing will be preferred over integration irrespective of α_P. This threshold is least binding (0.45) for $\theta = 0$ and falls to 0.21 for the highest realistic value for θ $(= \lambda)$. ■

Proof of Proposition 3

The welfare function is as before in equation (14). We now consider how complementarities affect the difference between W^{VIB} and W^O:

$$\begin{aligned}\frac{\partial \Delta W}{\partial \alpha_{PS}} &= (\alpha_S + \alpha_{PS}x_P^{VIB} - x_S^{VIB})\frac{\partial x_S^{VIB}}{\partial \alpha_{PS}} + (\alpha_P + \alpha_{PS}x_S^{VIB} - x_P^{VIB})\frac{\partial x_P^{VIB}}{\partial \alpha_{PS}} + x_P^{VIB}x_S^{VIB} \\ &\quad - (\alpha_S + \alpha_{PS}x_P^O - x_S^O)\frac{\partial x_S^O}{\partial \alpha_{PS}} - (\alpha_P + \alpha_{PS}x_S^O - x_P^O)\frac{\partial x_P^O}{\partial \alpha_{PS}} - x_P^O x_S^O\end{aligned}$$

To evaluate this expression we need the partial derivatives of the investments with respect to the complementarities parameter:

$$\frac{\partial x_P^{VIB}}{\partial \alpha_{PS}} = \frac{\frac{1-\lambda^2}{4}\left[\alpha_S + 2\alpha_{PS}\alpha_P + \frac{1-\lambda^2}{4}\alpha_{PS}^2\alpha_S\right]}{(1-\frac{1-\lambda^2}{4}\alpha_{PS}^2)^2} \quad \text{and} \quad \frac{\partial x_S^{VIB}}{\partial \alpha_{PS}} = \frac{\frac{1-\lambda}{2}\left[\alpha_P + \frac{1-\lambda^2}{2}\alpha_{PS}\alpha_S + \frac{1-\lambda^2}{4}\alpha_{PS}^2\alpha_P)\right]}{(1-\frac{1-\lambda^2}{4}\alpha_{PS}^2)^2}$$

$$\frac{\partial x_P^O}{\partial \alpha_{PS}} = \frac{\frac{1+\theta}{4}\left[\alpha_S + \alpha_{PS}\alpha_P + \frac{1}{4}\alpha_{PS}^2\alpha_S\right]}{(1-\frac{1}{4}\alpha_{PS}^2)^2} \quad \text{and} \quad \frac{\partial x_S^O}{\partial \alpha_{PS}} = \frac{\frac{1+\theta}{4}\left[\alpha_P + \alpha_{PS}\alpha_S + \frac{1}{4}\alpha_{PS}^2\alpha_P\right]}{(1-\frac{1}{4}\alpha_{PS}^2)^2}$$

Note that if $\lambda = \theta = 1$ both derivatives are smaller under integration than under outsourcing. However, if $\lambda = \theta = 0$ it is always the case that $\frac{\partial x_P^{VIB}}{\partial \alpha_{PS}} > \frac{\partial x_P^O}{\partial \alpha_{PS}}$ and if α_P is sufficiently large relative to α_S (more likely if the organizational form is VIB) we also find that $\frac{\partial x_S^{VIB}}{\partial \alpha_{PS}} > \frac{\partial x_S^O}{\partial \alpha_{PS}}$.

Substituting all these expressions in the partial derivative of ΔW, it is impossible to determine its sign in general. However, the expressions simplify considerably at low levels of complementarities, hence we will focus on $\left.\frac{\partial \Delta W}{\partial \alpha_{PS}}\right|_{\alpha_{PS}\to 0}$, calculating the derivative at the limit for α_{PS} going to zero. In this case both the optimal investments and the partial derivatives simplify considerably to

$$x_P^{VIB} = \alpha_P \quad \text{and} \quad x_S^{VIB} = \tfrac{1-\lambda}{2}\alpha_S$$
$$x_P^O = \tfrac{1+\theta}{2}\alpha_P \quad \text{and} \quad x_S^O = \tfrac{1+\theta}{2}\alpha_S$$

and

$$\frac{\partial x_P^{VIB}}{\partial \alpha_{PS}} = \tfrac{1-\lambda^2}{4}\alpha_S \quad \text{and} \quad \frac{\partial x_S^{VIB}}{\partial \alpha_{PS}} = \tfrac{1-\lambda}{2}\alpha_P$$
$$\frac{\partial x_P^O}{\partial \alpha_{PS}} = \tfrac{1+\theta}{4}\alpha_S \quad \text{and} \quad \frac{\partial x_S^O}{\partial \alpha_{PS}} = \tfrac{1+\theta}{4}\alpha_P.$$

If $\lambda = \theta = 0$, the only difference is that underinvestment is greater for the producer under O than under VIB, and the supplier's investment is more responsive to an increase in complementarities in VIB relative to O.

After some algebra, the derivative of interest boils down to

$$\frac{\partial \Delta W}{\partial \alpha_{PS}}\Big|_{\alpha_{PS}\to 0} \quad = \quad \tfrac{1}{4}\alpha_P\alpha_S\left[(1-\lambda)(3+\lambda)-2(1+\theta)\right] \; > \; 0 \qquad \text{if } \lambda < \overline{\lambda}(\theta) \tag{15}$$

Over the relevant range ($\lambda \in [0,1]$ and $\theta \in [0,\lambda]$), this is decreasing in λ and θ. For $\lambda < \sqrt{5}-2 \approx 0.24$ it is always positive, even if $\theta = \lambda$ (the maximum value of θ). If $\theta = 0$, the expression remains positive as long as $\lambda < \sqrt{2}-1$. Clearly, the highest λ that still makes (15) positive is decreasing in θ. At the extremes, the expression is guaranteed to be positive if $\lambda = 0$ and certainly negative if $\lambda = 1$, irrespective of θ.

Moreover, if we do not take the limit for $\alpha_{PS} \to 0$, but only $\alpha^2_{PS} \to 0$ the expressions simplify not as much, but enough to establish that the λ threshold for the expression in (15) to be positive is raised. The comparative static now becomes

$$\begin{aligned}
\frac{\partial \Delta W}{\partial \alpha_{PS}}\Big|_{\alpha^2_{PS}\to 0} \quad &= \quad \frac{\partial \Delta W}{\partial \alpha_{PS}}\Big|_{\alpha_{PS}\to 0} \\
&\quad + \; \alpha_P^2\alpha_{PS}\Big[\frac{(1-\lambda)(3+\lambda)}{4} - \frac{(1+\theta)(4+2\theta)}{32}\Big] \\
&\quad + \; \alpha_S^2\alpha_{PS}\Big[\frac{1-\lambda}{2}\frac{1+\lambda}{2}(1+\frac{1-\lambda}{2}+(\frac{1-\lambda}{2})^2) - \frac{(1+\theta)(4+2\theta)}{32}\Big] \\
&= \quad \frac{\partial \Delta W}{\partial \alpha_{PS}}\Big|_{\alpha_{PS}\to 0} + f(\lambda,\theta) \qquad \text{with } f(\overline{\lambda}(\theta),\theta) > 0
\end{aligned}$$

In general, this relaxes the constraint on λ for the marginal effect of α_{PS} to still be positive. The extent to which the constraint is relaxed depends on the parameters in the surplus production function (α_P, α_S, and α_{PS}), but as long as they are positive the constraint on λ becomes less binding. Evaluated at its stringiest level, i.e. at $\theta = \lambda$, the terms in the square brackets would be positive at 0.41, the earlier threshold. At $\theta = 0$, the first term in square brackets only becomes negative for $\lambda > 0.87$ and the second term is positive even for $\lambda = 1$. ■

Figure 1: Marginal effect of investments on outsourcing at low complementarity

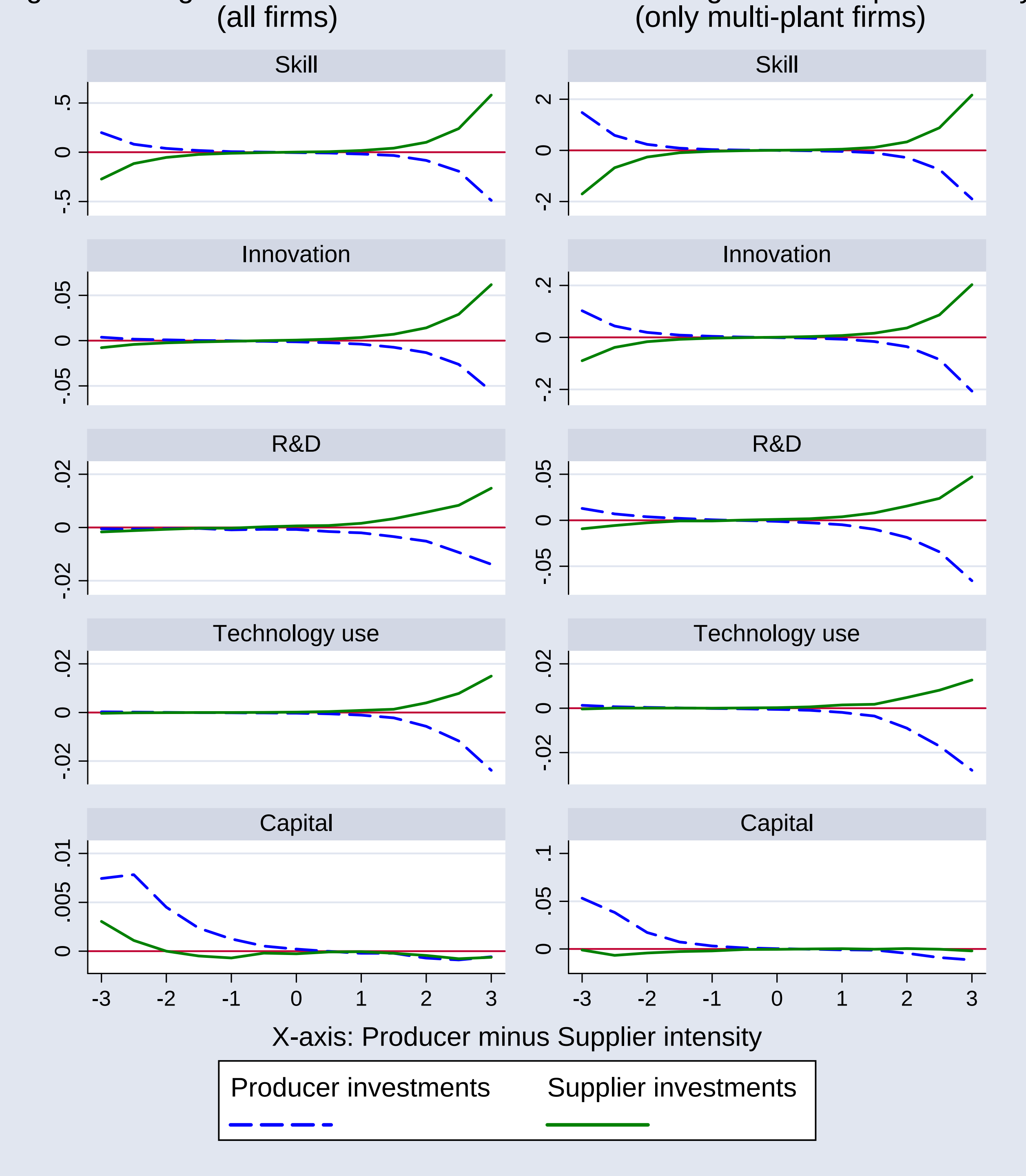

Figure 2: Marginal effect of skill intensity on outsourcing for various levels of complementarities

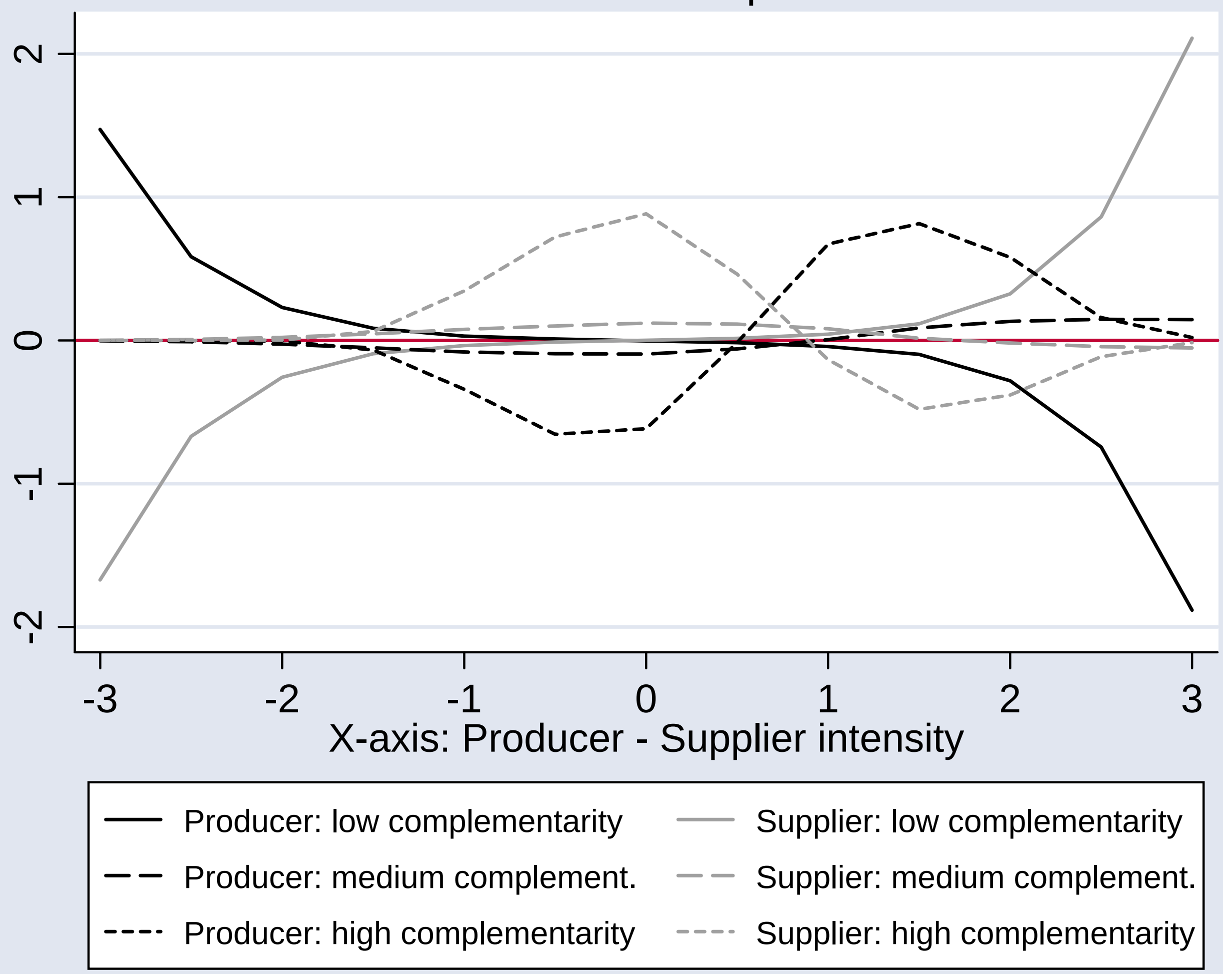

Figure 3: Marginal effect of skill intensity on outsourcing
for various levels of specificy

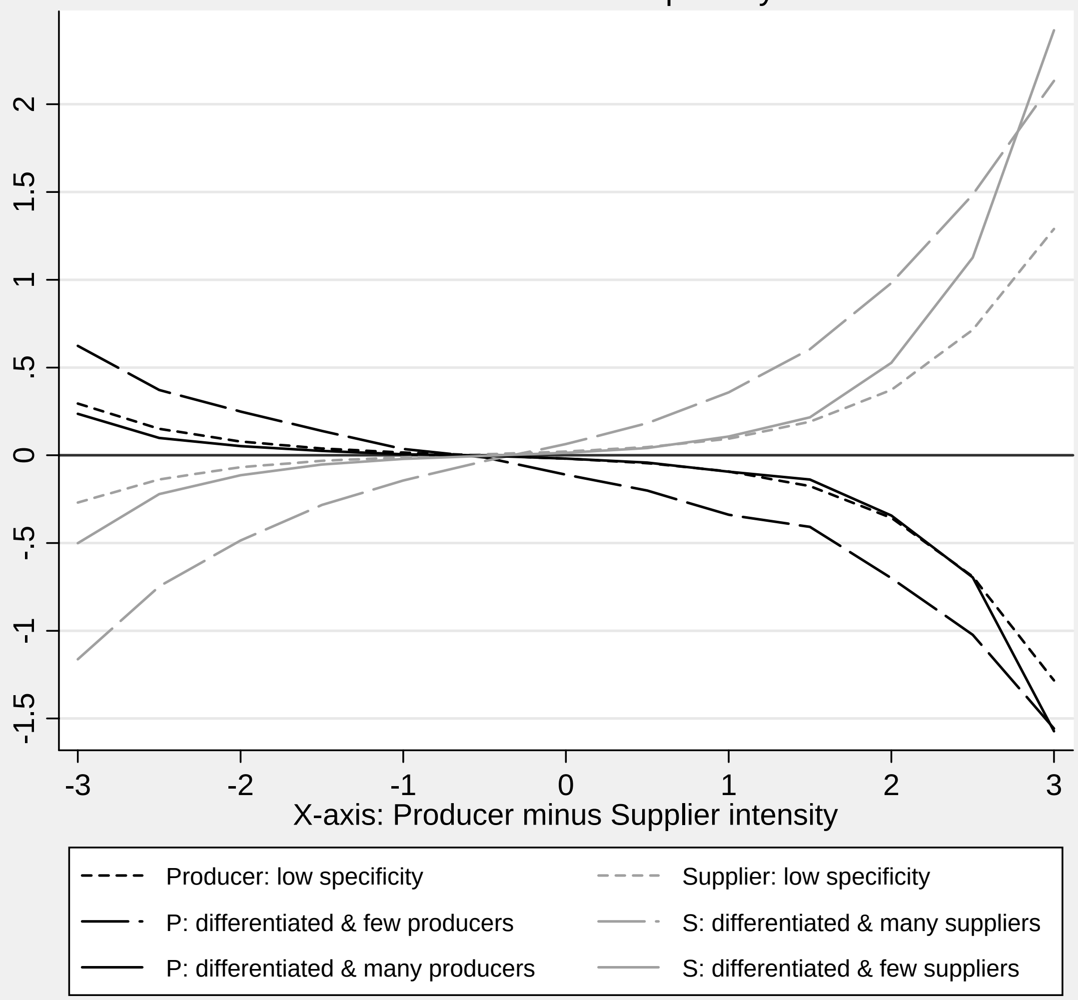

Figure 4: Marginal effect of investment intensities on outsourcing
(for low complementarities and high specificity)

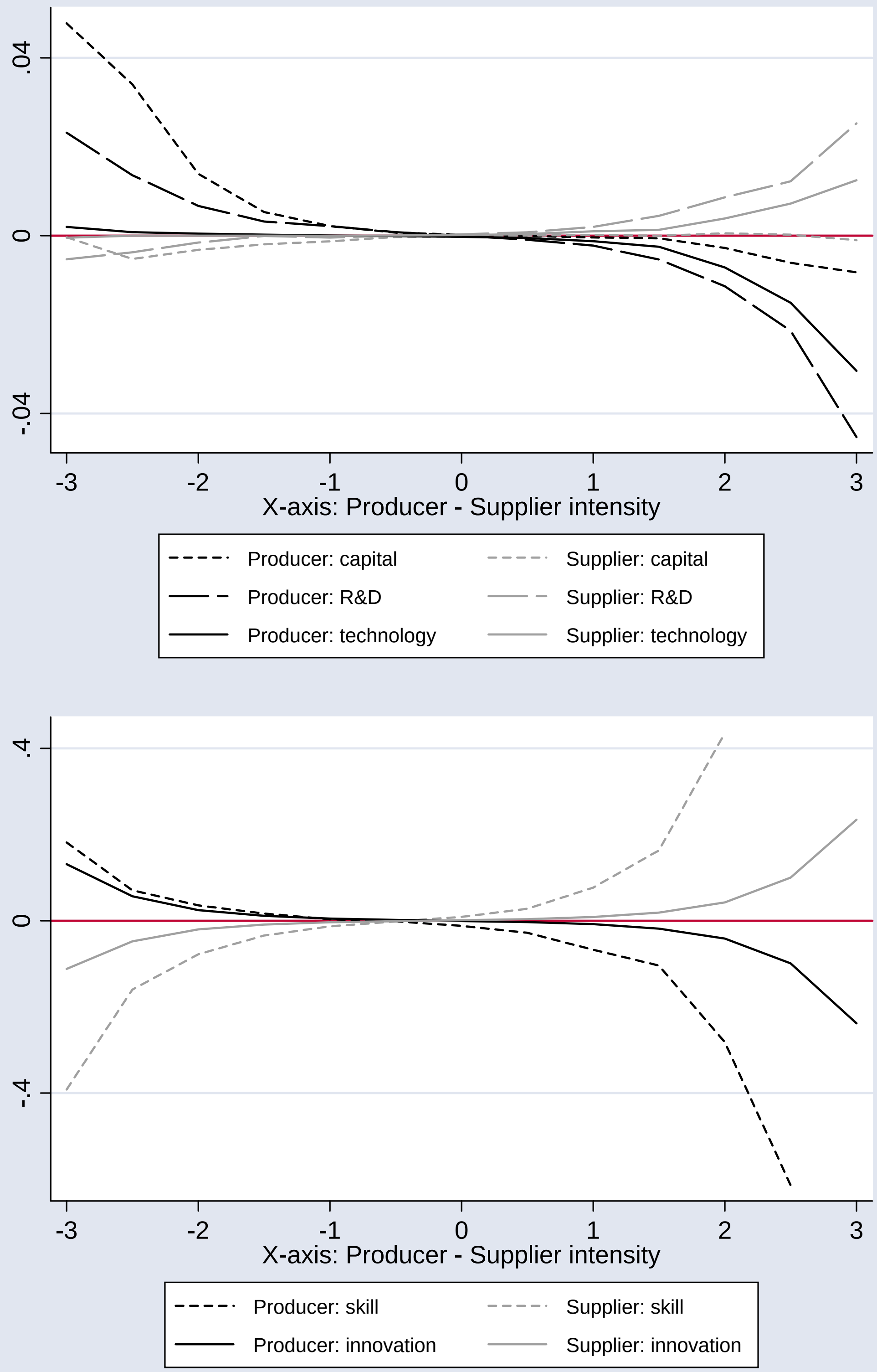

Table 1. Correlations between different technological intensities

	Skill	Innovation	R&D	Technology use	Capital
Skill	1				
Innovation	0.30	1			
R&D	0.44	0.44	1		
Technology use	0.38	0.56	0.35	1	
Capital	0.32	0.20	0.06	0.35	1

Notes: partial correlation statistics between the producer's technology intensity measures

Table 2: Importance of specificity

	Dependent variable is firm-commodity outsourcing indicator								
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Size	-0.128***	-0.127***	-0.122***	-0.139***	-0.126***	-0.126***	-0.128***	-0.139***	-0.129***
	(0.013)	(0.016)	(0.013)	(0.015)	(0.013)	(0.014)	(0.013)	(0.015)	(0.013)
$Size^P$	-0.038	-0.019	-0.032	-0.034	-0.037	-0.014	-0.023	-0.031	-0.035
	(0.035)	(0.042)	(0.034)	(0.037)	(0.041)	(0.033)	(0.040)	(0.037)	(0.043)
$Size^S$	0.237***	0.261***	0.238***	-0.020	0.217***	0.086*	0.228***	-0.035	0.206***
	(0.061)	(0.073)	(0.061)	(0.047)	(0.056)	(0.050)	(0.061)	(0.047)	(0.057)
Age	0.059**	0.045	0.058**	0.013***	0.058*	0.013	0.059**	0.013	0.057**
	(0.030)	(0.037)	(0.030)	(0.036)	(0.030)	(0.035)	(0.030)	(0.036)	(0.029)
Age^P	-0.032**	-0.045***	-0.032**	-0.054***	-0.031**	-0.051***	-0.031**	-0.056***	-0.028**
	(0.014)	(0.015)	(0.014)	(0.013)	(0.014)	(0.012)	(0.014)	(0.013)	(0.014)
Age^S	-0.033*	-0.053***	-0.034*	-0.012	-0.039**	-0.036**	-0.037**	-0.007	-0.033*
	(0.018)	(0.019)	(0.018)	(0.015)	(0.019)	(0.016)	(0.019)	(0.015)	(0.019)
Productivity	0.001	-0.012	0.004	-0.036	0.002	-0.022	0.002	-0.037	-0.008
	(0.033)	(0.036)	(0.032)	(0.034)	(0.033)	(0.033)	(0.033)	(0.034)	(0.032)
Non-production workers	-0.101	-0.135	-0.106	-0.232	-0.089	-0.207	-0.096	-0.231	-0.089
	(0.145)	(0.171)	(0.145)	(0.145)	(0.143)	(0.144)	(0.143)	(0.144)	(0.142)
Complexity	-0.124	-0.145	-0.118	-0.107	-0.109	-0.060	-0.132	-0.115	-0.087
	(0.090)	(0.100)	(0.090)	(0.095)	(0.099)	(0.095)	(0.093)	(0.094)	(0.101)
Cost share	-1.119***	-1.164***	-1.087***	-0.892***	-1.126***	-0.935***	-1.128***	-0.862***	-1.124***
	(0.096)	(0.113)	(0.098)	(0.095)	(0.094)	(0.096)	(0.094)	(0.094)	(0.093)
Complement	-1.643***	-1.742***	-1.633***	-1.742***	-1.627***	-1.654***	-1.631***	-1.749***	-1.571***
	(0.174)	(0.209)	(0.176)	(0.168)	(0.177)	(0.160)	(0.178)	(0.168)	(0.182)
$Rauch_j$		-0.086							
		(0.095)							
Fraction of $demand_{fj}$			-0.228***						
			(0.072)						
log $Producers^{COM}$				0.282***				0.349***	
				(0.025)				(0.034)	
log $Suppliers^{COM}$				-0.462***				-0.371***	
				(0.024)				(0.052)	
log $Producers^{IND}$					0.004				0.276***
					(0.045)				(0.101)
log $Suppliers^{IND}$					-0.042				0.248***
					(0.040)				(0.084)
$(\text{log Prod - log Supp})^{COM}$						0.368***			
						(0.020)			
$(\text{log Prod - log Supp})^{IND}$							0.025		
							(0.458)		
$(\text{log Prod x log Supp})^{COM}$								-0.024*	
								(0.012)	
$(\text{log Prod x log Supp})^{IND}$									-0.061***
									(0.019)
Observations	50179	44769	50179	43352	50179	43352	50179	43352	50,179
log likelihood	-12209	-9802	-12195	-10057	-12200	-10284	-12204	-10041	-12,114

Notes: Coefficient estimates from Probit estimations pooling two years (1988 and 1996), standard errors (clustered at industry level) in brackets. ***Significant at the 1% level, **5%, *10%.

Table 3(a): Simple property rights model

II =	Dependent variable is firm-commodity outsourcing indicator Skill (1)	 Innovation (2)	 R&D (3)	 Tech. use (4)	 Capital (5)
Producer Investment Intensity (II^P)	-1.362***	-0.456**	0.140	-0.061**	-0.044*
	(0.368)	(0.223)	(0.222)	(0.026)	(0.024)
Supplier Investment Intensity (II^S)	2.324***	1.274***	0.848***	0.126***	0.030*
	(0.321)	(0.194)	(0.155)	(0.028)	(0.016)
Observations	53632	50404	50404	50404	53971
log likelihood	-13249	-12268	-12413	-12481	-13561

Table 3(b): Property rights model with investment interactions

II =	Dependent variable is firm-commodity outsourcing indicator Skill (1)	 Innovation (2)	 R&D (3)	 Tech. use (4)	 Capital (5)
Producer Investment Intensity (II^P)	-1.367***	-0.522**	0.106	-0.073**	-0.019
	(0.419)	(0.241)	(0.229)	(0.031)	(0.031)
Supplier Investment Intensity (II^S)	2.062***	1.207***	0.736***	0.113***	0.033*
	(0.329)	(0.201)	(0.174)	(0.026)	(0.017)
$(II^P-II^S)^2$	8.901***	0.878**	1.081***	0.028***	0.027***
	(2.303)	(0.350)	(0.417)	(0.009)	(0.007)
Observations	53632	50404	50404	50404	53971
log likelihood	-13131	-12239	-12370	-12429	-13376

Table 3(c): Property rights model with investment and complementarity interactions

II =	Dependent variable is firm-commodity outsourcing indicator Skill (1)	 Innovation (2)	 R&D (3)	 Tech. use (4)	 Capital (5)
Producer Investment Intensity (II^P)	-0.969**	-0.545**	0.074	-0.077**	-0.003
	(0.397)	(0.231)	(0.219)	(0.030)	(0.029)
Supplier Investment Intensity (II^S)	1.569***	1.197***	0.745***	0.120***	0.021
	(0.285)	(0.190)	(0.172)	(0.027)	(0.018)
$(II^P-II^S)^2$	-12.591***	-2.170**	-0.770	-0.046*	-0.018
	(3.734)	(0.917)	(0.802)	(0.028)	(0.014)
$(II^P-II^S)^2$ x Complement	47.310***	5.929***	3.265*	0.126**	0.079***
	(8.305)	(2.005)	(1.739)	(0.053)	(0.028)
Observations	53632	50404	50404	50404	53971
log likelihood	-12976	-12184	-12350	-12379	-13320

Notes: Coefficient estimates from Probit estimations pooling two years (1988 and 1996), standard errors (clustered at industry level) in brackets. Results in each column use different measures of investment intensity (indicated at the top). Controls included are firm size, age, productivity, share of nonproduction workers, complexity, cost-share, complement, and a 1996 dummy. *** Significant at the 1% level, ** 5%, * 10%.

Table A.1 Summary statistics

	N	MEAN	STD
OUTS	50179	0.919	0.272
Cost-share	50179	0.125	0.226
Complement	50179	0.573	0.241
Specificity proxies			
log Producers^{IND}	50179	4.736	1.346
log Suppliers^{IND}	50179	4.147	1.293
log $(\text{Prod- Supp})^{IND}$	50179	0.590	1.737
log Producers^{COM}	50179	3.684	1.383
log Suppliers^{COM}	43352	2.207	1.459
log $(\text{Prod- Supp})^{COM}$	43352	1.658	1.466
Fraction_{fj}	50179	0.073	0.189
Rauch_{j}	44769	0.440	0.496
Investment intensities (industry level)			
$\text{II}^{P}_{K/L}$	50179	3.602	1.562
$\text{II}^{S}_{K/L}$	50179	3.834	1.796
$(\text{II}^{P}\text{-II}^{S})^{2}_{K/L}$	50179	4.686	7.968
II^{P}_{skill}	50090	0.452	0.118
II^{S}_{skill}	49933	0.493	0.118
$(\text{II}^{P}\text{-II}^{S})^{2}_{skill}$	49845	0.014	0.021
$\text{II}^{P}_{R\&D}$	50072	0.361	0.225
$\text{II}^{S}_{R\&D}$	50171	0.409	0.206
$(\text{II}^{P}\text{-II}^{S})^{2}_{R\&D}$	50064	0.066	0.112
II^{P}_{tech}	50072	1.734	1.239
II^{S}_{tech}	50171	2.129	1.168
$(\text{II}^{P}\text{-II}^{S})^{2}_{tech}$	50064	2.428	4.067
II^{P}_{innov}	50072	0.272	0.200
II^{S}_{innov}	50171	0.374	0.214
$(\text{II}^{P}\text{-II}^{S})^{2}_{innov}$	50064	0.066	0.112
Firm level controls			
Size	50179	2.072	1.687
Age	50179	0.271	0.471
Productivity	50179	0.544	0.608
Non-production workers	50179	0.018	0.157
Industry level controls			
Complexity	50179	3.995	0.410
Size^{P}	50179	4.406	1.300
Size^{S}	50179	4.639	1.185
Age^{P}	50179	16.477	3.308
Age^{S}	50179	17.085	3.679

Table A.2(a): Robustness check for property rights model: multi-plant firms

	Dependent variable is firm-commodity outsourcing indicator				
II =	Skill	Innovation	R&D	Tech. use	Capital
	(1)	(2)	(3)	(4)	(5)
Producer Investment Intensity (II^P)	-0.858***	-0.333*	0.095	-0.055**	-0.004
	(0.334)	(0.202)	(0.209)	(0.026)	(0.027)
Supplier Investment Intensity (II^S)	1.837***	1.181***	0.886***	0.089***	0.029
	(0.317)	(0.175)	(0.162)	(0.021)	(0.018)
$(II^P - II^S)^2$	-15.142***	-1.773**	-0.449	-0.052***	-0.023*
	(3.859)	(0.733)	(0.688)	(0.019)	(0.012)
$(II^P - II^S)^2$ x Complement	42.137***	4.718***	2.459*	0.148***	0.071***
	(8.439)	(1.513)	(1.512)	(0.037)	(0.022)
Observations	24756	24808	24808	24808	24836
log likelihood	-6867.2	-6928.6	-6997	-7045.5	-7037.6

Table A.2(b): Robustness check for property rights model: 1996 observations

	Dependent variable is firm-commodity outsourcing indicator				
II =	Skill	Innovation	R&D	Tech. use	Capital
	(1)	(2)	(3)	(4)	(5)
Producer Investment Intensity (II^P)	-1.047**	-0.526*	0.117	-0.044	0.017
	(0.478)	(0.300)	(0.250)	(0.034)	(0.031)
Supplier Investment Intensity (II^S)	1.824***	1.254***	0.783***	0.129***	0.029
	(0.394)	(0.232)	(0.221)	(0.032)	(0.018)
$(II^P - II^S)^2$	-18.248***	-1.761	-0.228	-0.031	-0.015
	(5.435)	(1.196)	(0.983)	(0.037)	(0.017)
$(II^P - II^S)^2$ x Complement	52.824***	5.881**	2.762	0.097	0.082***
	(10.731)	(2.874)	(2.100)	(0.066)	(0.030)
Observations	23339	23449	23449	23449	23506
log likelihood	-5571.7	-5566.7	-5655.8	-5687.5	-5673.9

Notes: Coefficient estimates from Probit estimations pooling two years (1988 and 1996), standard errors (clustered at industry level) in brackets. Results in each column use different measures of investment intensity (indicated at the top). Controls included are firm size, age, productivity, share of nonproduction workers, complexity, cost-share, complement, and a 1996 dummy. *** Significant at the 1% level, ** 5%, * 10%.

Table A.3: Full set of results for flexible property rights model (coefficient estimates)

	Dependent variable is firm-commodity outsourcing indicator				
II =	Skill	Innovation	R&D	Tech. use	Capital
	(1)	(2)	(3)	(4)	(5)
Size	-0.047***	-0.055***	-0.055***	-0.051***	-0.051***
	(0.016)	(0.017)	(0.017)	(0.019)	(0.017)
Age	0.102***	0.127***	0.130***	0.115***	0.113***
	(0.034)	(0.035)	(0.033)	(0.034)	(0.034)
Non-production workers	-0.115	-0.106	-0.063	-0.029	-0.100
	(0.143)	(0.140)	(0.139)	(0.144)	(0.147)
Productivity	-0.005	-0.001	-0.005	-0.001	-0.004
	(0.030)	(0.030)	(0.030)	(0.029)	(0.028)
Cost share	-1.314	-1.336***	-0.855**	-0.856***	-1.695***
	(1.309)	(0.322)	(0.362)	(0.269)	(0.520)
Complexity	0.162	-0.056	-0.118	-0.046	0.008
	(0.116)	(0.119)	(0.115)	(0.111)	(0.122)
Complement	-5.032***	-2.796***	-3.172***	-2.70***	-2.492***
	(1.536)	(0.592)	(0.749)	(0.735)	(0.585)
II^P	-0.603	-2.417	-3.969**	-0.367	0.197
	(5.455)	(1.561)	(1.741)	(0.271)	(0.195)
II^S	-7.060	-1.833	-1.883	-0.445	-0.966***
	(5.460)	(1.815)	(1.464)	(0.307)	(0.239)
$II^P \times II^S$	13.787	1.815	2.191	0.180***	-0.023
	(10.418)	(2.055)	(1.614)	(0.066)	(0.034)
$(II^P)^2$	-6.063	1.896	2.626	-0.039	-0.006
	(6.751)	(1.821)	(1.798)	(0.045)	(0.028)
$(II^S)^2$	-0.095	1.467	1.564	0.018	0.123***
	(7.352)	(2.273)	(1.626)	(0.061)	(0.032)
(II^P) x Complement	1.948	2.781	3.159	0.365	-0.447
	(8.292)	(2.798)	(2.651)	(0.406)	(0.317)
(II^S) x Complement	10.905	4.001	4.179*	0.623	0.891***
	(8.401)	(2.819)	(2.275)	(0.448)	(0.352)
$(II^P \times II^S)$ x Complement	-88.228***	-13.075***	-6.987**	-0.398***	-0.127***
	(19.846)	(3.572)	(3.293)	(0.096)	(0.043)
$(II^P)^2$ x Complement	41.974***	3.467	1.194	0.172**	0.102**
	(13.400)	(3.032)	(2.741)	(0.077)	(0.049)
$(II^S)^2$ x Complement	35.104***	1.574	-1.518	0.027	-0.024
	(13.137)	(3.495)	(2.720)	(0.100)	(0.046)
(II^P) x Cost share	-5.160	0.574	1.230	-0.379*	0.465**
	(5.073)	(1.569)	(2.435)	(0.214)	(0.231)
(II^S) x Cost share	6.717	1.760	-2.006	-0.097	-0.103
	(6.290)	(2.271)	(1.872)	(0.239)	(0.175)
$(II^P \times II^S)$ x Cost share	-42.894***	-5.454**	-9.279***	-0.046	-0.058**
	(11.565)	(2.541)	(3.414)	(0.053)	(0.026)
$(II^P)^2$ x Cost share	23.607***	1.592	2.966	0.099**	-0.042
	(6.957)	(2.367)	(3.361)	(0.051)	(0.028)
$(II^S)^2$ x Cost share	17.257*	0.663	6.694***	0.077*	0.057**
	(9.790)	(2.104)	(2.395)	(0.046)	(0.023)
Rauch dummy	1.053	0.133	-0.122	-0.110	-0.256
	(0.839)	(0.266)	(0.322)	(0.268)	(0.388)
(II^P) x Rauch	-8.836***	-0.480	1.849**	0.127	0.118
	(2.818)	(0.959)	(0.776)	(0.151)	(0.107)
(II^S) x Rauch	5.644	1.129	-0.836	0.181	0.148
	(3.636)	(1.472)	(1.284)	(0.201)	(0.162)
$(II^P \times II^S)$ x Rauch	4.984	1.131	-0.811	0.018	0.006
	(7.038)	(1.618)	(1.223)	(0.036)	(0.019)
$(II^P)^2$ x Rauch	6.338	-0.042	-1.236	-0.037	-0.011
	(4.765)	(1.094)	(0.886)	(0.028)	(0.014)
$(II^S)^2$ x Rauch	-8.475	-2.146	1.505	-0.037	-0.021
	(5.679)	(1.896)	(1.419)	(0.047)	(0.022)
Multi-plant dummy	-0.934**	-0.484***	-0.710***	-0.282*	-0.423*
	(0.487)	(0.154)	(0.223)	(0.156)	(0.255)
(II^P) x Multi-plant	2.078	1.260	2.263**	0.190	-0.007
	(2.613)	(0.843)	(0.941)	(0.124)	(0.120)
(II^S) x Multi-plant	0.278	-0.819	-0.622	-0.328**	0.031
	(2.872)	(0.816)	(0.779)	(0.130)	(0.101)
$(II^P \times II^S)$ x Multi-plant	17.495***	4.296**	1.851	0.009	0.098***
	(6.866)	(1.783)	(1.264)	(0.043)	(0.024)
$(II^P)^2$ x Multi-plant	-10.737***	-3.527*	-3.504***	-0.044	-0.050***
	(4.083)	(1.860)	(1.253)	(0.034)	(0.019)
$(II^S)^2$ x Multi-plant	-8.884*	-0.507	0.096	0.067**	-0.045**
	(5.365)	(0.972)	(0.929)	(0.031)	(0.019)
log (# prod. / # suppl.)	0.181**	0.070***	0.072*	0.066**	0.035
(rel. #)	(0.104)	(0.028)	(0.039)	(0.032)	(0.031)
(II^P) x (rel. #)	-0.276	-0.121	-0.113	-0.028	0.018
	(0.354)	(0.108)	(0.152)	(0.022)	(0.013)
(II^S) x (rel. #)	0.026	0.412***	0.344**	0.069***	0.026**
	(0.457)	(0.141)	(0.141)	(0.024)	(0.012)
$(II^P \times II^S)$ x (rel. #)	0.137	-0.023	-0.246	-0.003	0.000
	(0.535)	(0.169)	(0.195)	(0.004)	(0.002)
$(II^P)^2$ x (rel. #)	0.043	0.044	0.224	0.005	-0.002
	(0.424)	(0.130)	(0.150)	(0.004)	(0.001)
$(II^S)^2$ x (rel. #)	-0.050	-0.456***	-0.313*	-0.010*	-0.003**
	(0.556)	(0.152)	(0.178)	(0.006)	(0.002)
Constant	3.351**	3.191***	3.958***	3.402***	3.508***
	(1.790)	(0.600)	(0.595)	(0.710)	(0.530)
Observations	40659	38451	38451	38451	40939
log likelihood	-9285.2	-8596.2	-8639.0	-8626.7	-9374.5

Notes: Coefficient estimates from Probit estimations pooling two years (1988 and 1996), standard errors (clustered at industry level) in brackets. Results in each column use different measures of investment intensity (indicated at the top). ***Significant at the 1% level, **5%, *10%.