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ABSTRACT

Outsourcing and Technological Innovations: A Firm-Level Analysis*

This paper presents a dynamic model that analyzes how firms' expectations with regards to technological change influence the demand for outsourcing. We show that outsourcing becomes more beneficial to the firm when technology is changing rapidly. As the pace of innovations in production technology increases, the firm has less time to amortize the sunk costs associated with purchasing the new technologies. This makes producing in-house with the latest technologies relatively more expensive than outsourcing. The model therefore provides an explanation for the recent increases in outsourcing that have taken place in an environment of increased expectations for technological change. We test the predictions of the model using a panel dataset on Spanish firms for the period 1990 through 2002. The empirical results support the main prediction of the model, namely, that all other things equal, the demand for outsourcing increases with the probability of technological change.

JEL Classification: O33, L24, L11, J21

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I. Introduction

Outsourcing, or the contracting out of activities to subcontractors outside the firm, has become more widespread in recent decades. For example, Magnani (2006) reports that the cost share of purchased services in U.S. manufacturing industries grew from 4.4% in 1949 to 12% in 1998. Similar increases in outsourcing have been observed in Europe as well.[1] A large theoretical literature has examined the determinants of the decision to outsource, or, more generally, the organization of production. Outsourcing parts of the production of a final product is costly because of the costs associated with searching and finding an appropriate input supplier and, more importantly, because contracting with outside suppliers may be imperfect if some attributes of the outsourced inputs are not verifiable by third parties. This limits contracting possibilities and creates a potential hold-up problem.[2] These ideas go back to Williamson (1975, 1985) and Grossman and Hart (1986) and have been recently incorporated into industry equilibrium models by Grossman and Helpman (2002) while their implications for international trade are analyzed in Antras and Helpman (2004).

In this paper we present a dynamic model that analyzes how firms' expectations with regards to technological change influences the demand for outsourcing – an issue not addressed in previous models – while abstracting from other considerations (e.g., transaction costs, specificity, etc.). We show that outsourcing becomes more beneficial to the firm when technology is changing rapidly. A firm can buy the latest technology and

[1] See Arndt and Kierzkowski (2001), Mol (2005) and Abramovsky and Griffith (2006).

[2] Baker and Hubbard (2003) consider how information technology in the trucking industry impacts contracting possibilities and vertical integration. Baccara (2007) uses a general equilibrium model to study how information leakages could affect a firm's outsourcing decision as well as its investments in R&D.

produce intermediate inputs in-house. Firms incur a sunk cost when adopting new technologies. Outsourcing, on the other hand, enables the firm to purchase inputs from supplying firms using the latest production technology while avoiding the new technology sunk costs. The intuition behind the model is that as the pace at which innovations in production technology arrive increases, the less time the firm has to amortize the sunk costs associated with purchasing the new technologies. This makes producing in-house with the latest technologies relatively more expensive than outsourcing, The model, therefore, provides an explanation for the recent increases in outsourcing that have taken place in an environment of increased expectations for technological change.

We test the predictions of the model using a panel dataset on Spanish firms for the period 1990 through 2002. This dataset is particularly useful for our purposes because, in each survey year, the firms were asked whether they contracted with third parties for the manufacturing of custom-made finished products or parts. In addition, the dataset contains information on the firm's R&D expenditures, an ideal proxy for expected technological change. Our econometric analysis controls for unobservable fixed characteristics of the firms and also uses instrumental variables techniques to deal with the potential endogeneity of our technological change measure. The empirical results support the main prediction of the theoretical model, namely, that all other things equal, the demand for outsourcing increases with the probability of technological change.

Ours is the first paper to provide both a theoretical and empirical analysis of the impact of technological change on outsourcing using firm-level panel data. Magnani (2006), using industry-level data for the U.S., found that outsourcing was facilitated by technological diffusion, while Abramovsky and Griffith (2006) found that information and communications technology-intensive firms in the U.K. were more likely to purchase a greater amount of services on the market. Other research has found evidence that firms engage in outsourcing in response to unpredictable variations in demand (Abraham and Taylor, 1996), to take advantage of the specialized knowledge of suppliers (Abraham and Taylor, 1996), and to save on labor costs (Autor, 2003; Diaz-Mora, 2005; and Girma and Gorg, 2004).[3]

Part II presents a dynamic model of the relationship between outsourcing and expected technological change. Part III discusses the data and empirical specifications used to test the predictions of the model. Results are presented in Part IV. Part V concludes.

II. A Model of the Demand for Outsourcing

A firm produces a profit-maximizing amount of output *y* using a single input *x*. The model focuses on determining how to procure a given level of input *x*. There are two ways of obtaining *x*. One way is to produce *x* in-house using *k* machines each with productivity θ according to the in-house production function

$$x = \theta k \tag{1}$$

The cost of producing in-house is

$$C_H = \left(\frac{p_k}{\theta}\right) x + s$$

[3] Other researchers (Ono (2007) and Holl (2007)) have studied the effect of agglomeration economies on outsourcing. For empirical studies of the impacts of outsourcing on wages and productivity, see Feenstra and Hanson (1999), Amiti and Wei (2006), Gorg, Hanley and Strobl (2007), and Gorg and Hanley (2007).

where p_k is the (rental) price of a machine and s is a sunk cost associated with installing and using the machines of a given productivity (or vintage) for the first time. s is incurred only once. This initial installation cost also reflects training costs.

The second way of procuring x is to buy it in the market. We call this outsourcing production. The cost of this alternative is

$$C_O = px$$

where p is the unit price of x.

We assume that outsourcing costs are the same across firms, but allow for heterogeneity in the sunk cost of in-house production by assuming that s is distributed among firms with distribution $G(s)$.

Assuming constant returns to scale in production we can, without loss of generality, set $x = y$ and write the costs as functions of y (which is observable)

$$\begin{aligned} C_H &= \left(\frac{p_k}{\theta}\right) y + s \\ C_O &= py \end{aligned} \qquad (2)$$

As in Ono (2000), the firm chooses the procuring alternative that minimizes costs. Let $\chi = 1$ indicate a firm that outsources its production.[4] This simple model implies

[4] The constant returns to scale assumption implies that the firm either produces all y in-house or outsources all of y, therefore it is not optimal to split a given level of y between in-house and outsourcing. The cost of splitting y between in-house (y_H) and outsourcing (y_O) is $py_O + \left(\frac{p_k}{\theta}\right) y_H + s,$ where $y = y_O + y_H$. We can write this cost as $py - \left(p - \frac{p_k}{\theta}\right) y_H + s.$ It follows that producing all of y in-house minimizes costs when $p > \frac{p_k}{\theta}$, i.e., when outsourcing is expensive, and, conversely, outsourcing

$$\chi = \begin{cases} 1 \text{ if } C_O \le C_H \Leftrightarrow s > \left(p - \frac{p_k}{\theta}\right) y \\ \\ 0 \text{ else} \end{cases} \tag{3}$$

Suppose the price of *x* is above the marginal cost of in-house production.[5] Firms would then outsource only because the sunk cost of in-house production is relatively large; firms with low sunk costs will not outsource production. A larger production size decreases the likelihood of outsourcing because the sunk cost per unit of production decreases. Notice that if we do not allow for heterogeneity in *s* then *all* firms of a given size would be either outsourcing or producing in-house which is in general contrary to the facts.[6]

Introducing Technological Change

We extend this simple model of demand for outsourcing to allow for technological change in the production of *x*. Our goal is to examine the relationship between technological change and outsourcing. Since technological change is uncertain and occurs over time, we now introduce dynamics and uncertainty into the model. We focus, for simplicity, on a two-period model.

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all of *y* is preferred when $p < \frac{p_k}{\theta}$. Only when $p = \frac{p_k}{\theta}$ is the firm indifferent between in-house and outsourcing all or parts of its production. In reality, however, firms usually outsource part of their production, so that we should interpret *x* as one of multiple component of the final output produced by the firm.

[5] If the suppliers of *x* have a cost advantage in producing *x* and there is competition among suppliers the price of *x* could be below the marginal cost of in-house production. In this case, all firms will outsource *x*.

[6] We could have also added heterogeneity to the cost of outsourcing. The model would be equivalent because heterogeneity enters additively and what matters for the decision to outsource is the difference between C_O and C_H. In this case s may represent the additional cost of using a standardized input which is absent when x is produced in-house because then the firm can perfectly tailor the input to its specific needs.

Suppose that technology (i.e., the productivity of machines) in the first period is given by θ_1. In the second period, productivity can either increase to $\theta_2, \theta_2 > \theta_1,$ with probability λ or remain at θ_1 with the complementary probability, i.e.,

$$\theta = \begin{cases} \theta_2 \text{ with probability } \lambda \\ \\ \theta_1 \text{ with probability } 1-\lambda \end{cases}$$

At the beginning of each period, the firm decides to outsource or to produce in-house given the observed technology level and prices. We denote the price of *x* in period 1 by p_1. We assume that *x* is supplied by firms using the latest technologies. As production technology improves, firms can charge a lower price of *x* and still make profits. Whether they will do this or not depends on the competitive environment. We do not model the supply side here but allow the price of *x* to change as technology improves. We let $p_{2\lambda}$ be the price of *x* when a technological change occurs in the second period, and p_2 be the price of *x* when technology does not change. Because the price of machines does not change, their quality-adjusted price $\frac{p_k}{\theta}$ declines as technology improves.

We proceed backwards. Suppose there is technological change in the second period. The firm faces three alternatives: it can outsource, it can produce in-house with the old technology or it can pay the sunk cost and upgrade to the new vintage of machines. To simplify the analysis we make the assumption that upgrading always dominates keeping the old technology. This requires a not too large sunk cost, namely $s \leq p_k y\left(\frac{\theta_2-\theta_1}{\theta_1\theta_2}\right),$ which we assume to hold, i.e.,

$$G(s) = 1 \quad \text{for } s \geq p_k y\left(\frac{\theta_2 - \theta_1}{\theta_2\theta_1}\right) \tag{4}$$

In this case, the firm's decision is essentially as in the static model analyzed in the previous section: to outsource or to produce in-house. Because producing in-house requires incurring the sunk cost, the firm's decision in the first period does not affect its current decision. Then, as in (3), when there is a technological improvement, the demand for outsourcing is

$$\chi_2 = \begin{cases} 1 \text{ if } s \geq \left(p_{2\lambda} - \frac{p_k}{\theta_2}\right) y \\ \\ 0 \text{ else} \end{cases} \tag{5}$$

If there is no technological change, the firm's decision depends on its outsourcing decision in the first period. If the firm produced in-house in the first period, it already paid the sunk cost *s* for the use of the technology and therefore it will outsource only if $\frac{p_k}{\theta_1} y > p_2 y$. But, if the firm outsourced in the first period, the cost of using the old technology in-house is $\frac{p_k}{\theta_1} y + s$ which needs to be compared to the cost of outsourcing, $p_2 y$. This gives the following outsourcing decision in period 2 in the absence of technological change,

$$\chi_2 = \begin{cases} 1 \text{ if } \chi_1 \times s \geq \left(p_2 - \frac{p_k}{\theta_1}\right) y \\ \\ 0 \text{ else} \end{cases} \tag{6}$$

Because of the presence of sunk costs, the decision to outsource during the first period affects future decisions if technological change does *not* occur. Specifically, a firm that did not outsource during the first period, $\chi_1 = 0$, will be less likely to outsource during the second period if no technological change occurs.

In the first period, the firm chooses to outsource or produce in-house by comparing the expected discounted costs of each alternative. These costs are,

$$C(\chi_1 = 1) = p_1 y + \beta(1-\lambda) Min\left\{ p_2 y, \frac{p_k}{\theta_1} y + s \right\} + \beta\lambda Min\left\{ p_{2\lambda} y, \frac{p_k}{\theta_2} y + s \right\}$$

$$C(\chi_1 = 0) = \frac{p_k}{\theta_1} y + s + \beta(1-\lambda) Min\left\{ p_2 y, \frac{p_k}{\theta_1} y \right\} + \beta\lambda Min\left\{ p_{2\lambda} y, \frac{p_k}{\theta_2} y + s \right\}$$

where β is the discount factor.

The difference between these two costs is

$$\begin{aligned} C(\chi_1 = 1) - C(\chi_1 = 0) &= \left(p_1 - \frac{p_k}{\theta_1} \right) y - \left(1 - \beta(1-\lambda)\right) s + \\ &\beta(1-\lambda) Min\left\{ \left(p_2 - \frac{p_k}{\theta_1} \right) y - s, 0 \right\} - \beta(1-\lambda) Min\left\{ \left(p_2 - \frac{p_k}{\theta_1} \right) y, 0 \right\} \end{aligned}$$

which can be written as,

$$C(\chi_1 = 1) - C(\chi_1 = 0) = \begin{cases} \left(p_1 - \frac{p_k}{\theta_1} \right) y - s & \left(p_2 - \frac{p_k}{\theta_1} \right) y \le 0 \\ \left(p_1 - \frac{p_k}{\theta_1} \right) y + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1} \right) y - s, & 0 \le \left(p_2 - \frac{p_k}{\theta_1} \right) y \le s \\ \left(p_1 - \frac{p_k}{\theta_1} \right) y - \left(1 - \beta(1-\lambda)\right) s, & \left(p_2 - \frac{p_k}{\theta_1} \right) y \ge s \end{cases} \quad (7)$$

We can rule out the first case because it is reasonable to assume that the price of *x* in period 2 (the last period) cannot be below the marginal cost of in-house production, i.e.,[7]

$$p_2 \geq \frac{p_k}{\theta_1} \tag{8}$$

The firm decides to outsource in the first period whenever $C(\chi_1 = 1) - C(\chi_1 = 0) < 0$. The decision to outsource in the first period therefore depends on current and future prices of *x* as well as on the size of sunk costs and the probability of technological change λ,

$$\chi_1 = \begin{cases} 1 \text{ if } s \geq \left(p_1 - \frac{p_k}{\theta_1}\right) y + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1}\right) y \text{ and } s \geq \left(p_2 - \frac{p_k}{\theta_1}\right) y \\ 1 \text{ if } s \geq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right) y}{1-\beta(1-\lambda)} \text{ and } s \leq \left(p_2 - \frac{p_k}{\theta_1}\right) y \\ 0 \text{ else} \end{cases} \tag{9}$$

From (7) we see that, all other things equal, an increase in λ decreases the cost of outsourcing relative to that of in-house production making the firm more likely to decide to outsource in the first period. This is the main message of the model: when the likelihood of technological change increases, firms will be more reluctant to purchase the technology to produce in-house because it will soon be obsolete. Upgrading the technology involves incurring a sunk cost “di novo.” The more frequent the innovations arrive, the less time the firm has to amortize these sunk costs. The firm can use outsourcing to obtain *x* from supplying firms using the latest technology and avoid the sunk costs.

[7]This assumption depends on the type of technology and competition among the firms producing *x*.

Empirical Implications

We use this simple model of the demand for outsourcing to generate a reduced-form equation for the demand for outsourcing in any period.

There are three different threshold values in (9) that determine the demand for outsourcing in period 1: $\left(p_1 - \frac{p_k}{\theta_1}\right)y + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1}\right)y$, $\left(p_2 - \frac{p_k}{\theta_1}\right)y$ and $\frac{\left(p_1 - \frac{p_k}{\theta_1}\right)y}{1-\beta(1-\lambda)}$. Because demand for outsourcing depends on *s* being above or below these thresholds, their relative magnitudes are important. Among the different ways these three thresholds can be ranked, only two configurations are feasible, namely,

$$\left(p_2 - \frac{p_k}{\theta_1}\right) \gtrless \left(p_1 - \frac{p_k}{\theta_1}\right) + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1}\right) \gtrless \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)}$$

which can we written more compactly as

$$\left(p_2 - \frac{p_k}{\theta_1}\right) \gtrless \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)}$$

Thus, $\left(p_2 - \frac{p_k}{\theta_1}\right) \gtrless \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)}$ defines two price regions which determine demand for outsourcing in the first period,

$$\chi_1 = \begin{cases} 1 \ \text{ if } s \geq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)y}{1-\beta(1-\lambda)} \ \text{ when } \left(p_2 - \frac{p_k}{\theta_1}\right)y \geq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)y}{1-\beta(1-\lambda)} \\ \\ 1 \ \text{ if } s \geq \left(p_1 - \frac{p_k}{\theta_1}\right)y + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1}\right)y \ \text{ when } \left(p_2 - \frac{p_k}{\theta_1}\right)y \leq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)y}{1-\beta(1-\lambda)} \\ \\ 0 \ \text{ else} \end{cases}$$

which implies

$$E(\chi_1) = \begin{cases} 1 - G\left(\frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)} y\right) \ \text{ when } \left(p_2 - \frac{p_k}{\theta_1}\right) \geq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)} \\ \\ 1 - G\left(\left(p_1 - \frac{p_k}{\theta_1}\right)y + \beta(1-\lambda)\left(p_2 - \frac{p_k}{\theta_1}\right)y\right) \ \text{ when } \left(p_2 - \frac{p_k}{\theta_1}\right) \leq \frac{\left(p_1 - \frac{p_k}{\theta_1}\right)}{1-\beta(1-\lambda)} \end{cases}$$

Notice that, for given prices, $1 - G(\cdot)$ increases with λ so that the demand for outsourcing in period 1 is increasing in the probability of technological change λ.

The demand for outsourcing in period 2 is given by

$$\begin{aligned} E\left(\chi_2\right) &= \lambda E\left(\chi_2 \,|\, T_2 = 1\right) \\ &\quad + (1-\lambda)\left[E\left(\chi_2 \,|\, T_2 = 0, \chi_1 = 1\right)E(\chi_1) + E\left(\chi_2 \,|\, T_2 = 0, \chi_1 = 0\right)\left(1 - E(\chi_1)\right)\right] \end{aligned}$$

where T_2 is an indicator for technological change occurring in period 2.

In this simple model, $E\left(\chi_2 \,|\, T_2 = 0, \chi_1 = 0\right) = 0$ because a firm that did not outsource in the first period will continue producing in-house in the second period if θ does not change. Expected outsourcing demand in the second period is therefore

$$E\left(\chi_2\right) = \lambda\left[1 - G\left(\left(p_{2\lambda} - \frac{p_k}{\theta_2}\right)y\right)\right] + (1-\lambda)\left[1 - G\left(\left(p_2 - \frac{p_k}{\theta_1}\right)y\right)\right]E(\chi_1) \qquad (10)$$

Given prices, $E(\chi_2)$ is an increasing function of λ when the price margin after an innovation occurs, $p_{2\lambda} - \frac{p_k}{\theta_2}$, is no larger than the price margin when there is no technology change, $p_2 - \frac{p_k}{\theta_1}$. This sufficient condition is likely to hold under many market structures because the number of potential outsourcers is larger after an innovation occurs prompting supplying firms to lower their markups in order to capture a larger market share.

III. Data and Empirical Specification

We use the Encuesta sobre Estrategias Empresariales (ESEE, or Survey on Business Strategies), a panel of approximately 1800 Spanish manufacturing companies, surveyed annually since 1990. Data are currently available through 2002. The survey is conducted by the Fundacion SEPI with the support of the Ministry of Industry, Tourism and Trade. We use data from the 1990, 1994, 1998 and 2002 surveys.[8]

In each survey, the firms were asked if they contracted with third parties for the manufacture of custom-made finished products or parts, and if so, the value of the outsourced products or parts. We use this information to create two indicators of outsourcing, a dummy for whether or not the firm did engage in outsourcing, and the value of outsourcing divided by total costs.[9] Table 1 shows, by industry sector and overall, the percentage of firms that reported outsourcing at least some part of production during the 1990–2002 time period and the mean value of the outsourced production as a

[8] Budgetary constraints prevented us from purchasing data for all of the years between 1990 and 2002.
[9] Lopez (2002) describes the evolution of outsourcing of services and of production in Spanish manufacturing firms using a sub-sample of the ESSE data for the period 1990-1999. He finds significant differences in outsourcing between small and large firms and a positive effect of outsourcing on productivity.

percentage of total cost. On average, 41% of firms reported that they outsourced production during this time period. The outsourcing percentage rose from 35% in 1990 to 43% in 2002. There is significant variation in the likelihood of outsourcing across industries ranging from a low of 16% for Drinks to a high of 61% for Machinery and Mechanical Goods. The value of the outsourced production as a percentage of total costs is approximately 5 percent during this time period; for firms that did outsource production, the mean value of outsourced production as a percentage of total costs is 11 percent.

In the previous section, we derived the demand for outsourcing in period *t* as a function of the probability of technological change, output, and the various input prices and technology parameters. Notice that the demand function differs between periods 1 and 2 because of the dynamic nature of the problem and the finiteness of the model. We will ignore this issue in the empirical application because we implicitly assume that the data-generating process has been going on for some time so that the relationship between outsourcing and its drivers stabilizes over time. Under the assumption that input prices and technology parameters are common to all firms in an industry, these can be captured by industry dummies (ID). Thus,

$$E(\chi_t) = h(\lambda, y_t, ID_t) \tag{11}$$

Equation (11) is a reduced-form expression because all the arguments in the *h* function are exogenous in the model.[10] The main implication of the theoretical model is that, all

[10]Equation (10) is a dynamic equation that could also serve as the basis for estimating the relationship between outsourcing and λ. It is, however, specific to a 2-period model. In a model with 3 or more periods the dynamics are much more complicated. We therefore prefer to estimate reduced form equations.

other things equal, the demand for outsourcing increases with the exogenous probability of technological change λ.

In order to test this implication we need a proxy for λ. We will proxy λ by an binary variable indicating whether a firm engages in R&D, and if it does, we will also use the amount of R&D expenditures. The rationale for this proxy is that a firm that engages in R&D is more likely to experience technological change (new processes and/or new products) as compared to a firm that does not engage in R&D. Table 1 shows that during the time period under study, 36 percent of the firms in the sample engaged in R&D, with this percentage ranging from a low of 13% for Editing and Printing to 67% for Chemicals.

We make separability and linearity assumptions on the function *h*,

$$\chi_{it} = \beta_r r_{it} + \beta_y y_{it} + \sum_j \delta_j ID_{ij} + u_{it} \quad (12)$$

where r_{it} is our measure of R&D (a dummy for being engaged in R&D and/or the ratio of R&D expenditures to sales) and $ID_{ij} = 1$ if firm i is in industry *j* and zero otherwise. By using the two measures of r_{it} we are able to study whether the extensive or the intensive margin of R&D is more important in explaining outsourcing. We will estimate this equation for all years using clustered standard errors at the firm level to account for heteroskedasticity and arbitrary serial correlation.

Although the model assumes λ to be exogenous, a serious concern is that the probability that the firm will experience technological change is determined by unobserved factors that also affect the decision to outsource. More innovative firms may be doing more R&D and may also be adopting new production methods that require more outsourcing, i.e., λ, or its R&D proxy, may be endogenous in the outsourcing equation. The estimated R&D coefficient will therefore not capture the causal effect of technological change on outsourcing. We address this concern by allowing for a time-invariant component in u_{it} to affect both the decision to engage in R&D (and therefore λ) and the decision to outsource, i.e., $u_{it} = \mu_i + \eta_{it}$. Consistent estimates under this assumption can be obtained from time-differencing equation (12)

$$\chi_{it} - \chi_{it-1} = \beta_r\left(r_{it} - r_{it-1}\right) + \beta_y\left(y_{it} - y_{it-1}\right) + \eta_{it} - \eta_{it-1} \qquad (13)$$

and estimating this equation by OLS period by period. These estimates are consistent provided *R&D* is strictly exogenous.

The strict exogeneity assumption is quite strong because it precludes any correlation between shocks that affected outsourcing in previous periods and current R&D expenditures. We therefore make a weaker assumption that allows for outsourcing to affect future R&D expenditures,

$$E(\eta_{it} \mid r_{it}, r_{it-1}, \ldots) = 0 \qquad (14)$$

Under this assumption, we can use the lag of R&D as an instrument for $r_{it} - r_{it-1}$ in equation (13) to obtain consistent estimates of the parameters.

Equation (12) includes, in addition to the proxy for technological change, the firm's annual sales **(**Sales**)** as well as a vector of industry dummies. We also add two variables that measure the firm's current technological intensity, whether it uses computerized digital machine tools (*comp_dmt*) or uses robotics (c*omp_robotic*)**.** [11]

In order to control for factors other than technological change that may contribute to outsourcing, we also include a set of variables that have been the focus of previous research on the determinants of outsourcing. Since firms may use outsourcing as a way of economizing on labor costs (see Abraham and Taylor, 1996), we include the firm's average labor cost defined as total annual spending (wages and benefits) on "staff" divided by total employment (*wage*). Outsourcing may also be used to smooth the workload of the core workforce during peaks of demand (Abraham and Taylor, 1996; Holl, 2007). Hence, we add a measure of capacity utilization (*capacity)* defined as the average percentage of the standard production capacity used during the year. Small firms would be expected to be more likely to outsource because it may not be optimal for them to carry out all steps in the production process because of the costs of maintaining specialized equipment or skills in-house (Abraham and Taylor, 1996). Hence we control for the size of the firm using four categories for number of employees. Another factor that can increase the propensity to outsource is the volatility in demand for the product (Abraham and Taylor, 1996; Holl, 2007). We control for this by adding dummy variables for whether the main market the company serves expanded (*market_expand*) or declined (*market_decline*) during the year. It has also been argued that older firms are more likely to outsource because they have had time to learn about the quality and reliability of potential subcontractors (Holl, 2007). We therefore include the age of the firm (*age*). Whether the firm primarily produces standardized products or custom products should also affect the propensity to outsource with firms focusing on product variety being more

[11] These two variables may also be correlated with technological change and their inclusion in the equation

likely to outsource some of their production; we therefore add a dummy variable indicating that the firm produces standardized products that are, in most cases, the same for all buyers (*std_product*). Finally, we control for the firm's export propensity, the value of its exports divided by its sales (*export*), and whether the firm has any foreign ownership (*foreign_own*). Both of these factors have been included in prior studies of outsourcing (Girma and Gorg, 2004; Diaz-Mora, 2005; and Holl, 2007).

IV. Results

We estimated Equation (12) using two dependent variables: whether or not the firm engaged in outsourcing and the value of the firm's outsourced production as a percentage of total costs. Results for the first dependent variable are shown in Table 2 and for the second in Table 3. Each table provides the coefficients on the R&D dummy using various approaches to estimating Equation (12). The coefficients on the other variables included in these regressions are shown in Appendix Tables A-1 and A-2.

Columns (1), (2) and (3) in Table 2 use OLS, probit and logit, respectively, to estimate Equation (12). We find remarkably similar results across these three columns; firms that engage in R&D are 11-12 percent more likely to outsource some part of their production. When we control for firm-specific time-invariant unobservable factors in Column (4), firms that engage in R&D are 9.5% more likely to outsource production. Using first-differences in column (5), the coefficient on R&D falls to 0.066 but is still very significant. Column (6) adds the R&D/sales ratio and we find that what matters is whether the firm engages in R&D, not its R&D-intensity. Finally, in column (7), we use

could weaken the measured effect of the R&D variable.

the first lag of R&D as an instrument for the growth rate of R&D.[12] Although the coefficient on R&D is no longer significant because of the doubling of the standard error, the magnitude of the coefficient is virtually identical to the coefficient reported in column (5).

The results in Appendix Table A-1 show that, in the cross-section, high wage firms, older firms, larger firms, firms that are in a product market that has experienced an increase or a decrease (as compared to no change), firms that use computerized digital machine tools or robotics, are all more likely to outsource. Foreign-owned firms are less likely to outsource. These results, however, change dramatically when we use fixed effects or first differences: none of these additional regressors are significant while the R&D variable remains significant.[13]

In Table 3, the dependent variable is the value of the outsourced production divided by total costs. Since 60 percent of the observations are zeroes, we use tobit regressions. The results in the first column indicate that the probability of outsourcing is 9 percent higher for firms that engage in R&D; this effect is very close to the results observed in columns (1), (2) and (3) in Table 2. Column (1) in Table 3 also shows that, for firms that do outsource, the ratio of outsourcing to total costs is 0.013 higher for firms that engage in R&D. Using the mean value of the dependent variable for firms that do outsource (see Table 1), the coefficient translates to an 11 percent increase in outsourcing. The regressions in Table 3 were also estimated using standard random

[12] We also tried using the first lag of the growth rate in R&D as an instrument and obtained very similar results – but less precise -- to those reported in column (7).

[13]The exception is the export propensity variable which is positive and significant in the fixed effects and first differences specifications, but not significant in the first differenced regression with IV.

effects tobit, a method of random effects tobit that controls for unobserved effects[14], and instrumental variables tobit. Although the impact of R&D on outsourcing is smaller using random effects, the coefficients are still significant. The results using IV tobit are very strong; the coefficients on R&D are significant for both the extensive and the intensive margins of outsourcing.

V. Conclusions

A large theoretical literature has examined the determinants of the decision to outsource, or, more generally, the organization of production. But previous models have ignored the role played by technological change. In this paper we present a model that fills this void. We show that outsourcing becomes more beneficial to the firm when technology is changing rapidly. The intuition behind the model is that the more frequently innovations in technology arrive, the less time the firm has to amortize the sunk costs associated with an obsolete technology. Outsourcing enables the firm to purchase from supplying firms that are using the latest technology and avoid the sunk costs. Our model, therefore, links technological change and outsourcing and explains why outsourcing has been increasing in recent decades when the pace of technological change has accelerated.

We test the predictions of the model using a panel dataset on Spanish firms for the time period 1990 through 2002. Our econometric analysis controls for unobservable fixed characteristics of the firms and also uses instrumental variables techniques to deal with the potential endogeneity of our technological change measure. The empirical results

[14]We follow the Chamberlain-like approach suggested in section 8.2 of Chapter 16 in Wooldridge (2002) and include the means (over time) of all the regressors to account for the correlation between the regressors

indicate that firms doing R&D are between 6 and 10 percent more likely to outsource than firms not engaged in R&D. This is consistent with the main prediction of the theoretical model that the demand for outsourcing increases with the probability of technological change. Interestingly, while the existing literature has found evidence that other variables play a role in the decision to outsource, we find no such evidence here when accounting for firm effects.

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and the unobserved firm effects.

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Table 1

Mean Values of Outsourcing and R&D, By Industry Sector (1990-2002)

Industry	Proportion of Firms Outsourcing Production	Value of Outsourcing Divided by Total Costs		Proportion of Firms Engaging in R&D
		All	If >0	
Meat-processing industry	0.162	0.008	0.045	0.213
Foodstuffs and tobacco	0.242	0.019	0.080	0.279
Drinks	0.161	0.023	0.138	0.342
Textiles	0.451	0.061	0.134	0.244
Leather and footware	0.339	0.050	0.147	0.222
Wood industry	0.291	0.033	0.116	0.140
Paper	0.296	0.024	0.080	0.343
Editing and Printing	0.56	0.076	0.137	0.130
Chemicals	0.388	0.025	0.066	0.669
Rubber and plastics	0.458	0.038	0.083	0.366
Non-metallic minerals products	0.258	0.021	0.081	0.325
Iron and steel	0.284	0.023	0.082	0.555
Metallic Products	0.463	0.053	0.112	0.280
Machinery and mechanical goods	0.613	0.098	0.161	0.530
Office machinery, computers, processing	0.589	0.059	0.100	0.617
Electrical and electronic machinery	0.578	0.062	0.107	0.540
Motor vehicles	0.521	0.065	0.128	0.592
Other transport material	0.588	0.089	0.155	0.444
Furniture	0.367	0.041	0.113	0.216
Other manufacturing industries	0.503	0.050	0.098	0.287
All Industries (1990-2002)	0.412	0.047	0.114	0.364
1990 (N=2189)	0.351	0.042	0.120	0.340
1994 (N=1876)	0.416	0.044	0.107	0.364
1998 (N=1776)	0.467	0.054	0.117	0.381
2002 (N=1708)	0.429	0.048	0.112	0.375

Table 2

The Impact of R&D on the Likelihood of Outsourcing Production, 1990-2002[a]

Independent Variable	(1) OLS	(2) Probit	(3) Logit	(4) Logit (with fixed effects)	(5) First Differences	(6) First Differences	(7) First Differences and IV
R&D Dummy[b]	0.1127*** (0.016)	0.1203*** (0.017)	0.1215*** (0.018)	0.0949*** (0.033)	0.0663*** (0.023)	0.0723*** (0.025)	0.0580 (0.041)
R&D/Sales						0.0483 (0.5979)	
Observations	6977	6977	6977	2503	3838	3782	2063
R^2 /Pseudo R^2	0.13	0.10	0.10		0.006	0.007	
LR(chi^2)				78.57			14.23

[a] Dependent Variable: dummy variable equals one if firm outsourced some of its production; zero otherwise. All regressions include year dummies, industry dummies, and the set of control variables listed in the text. The complete regression results are given in the Appendix. Huber-White robust standard errors are in parentheses.

[b] Coefficients shown in columns (2) through (7) are the marginal effects calculated at the mean.

* Significant at 10%. ** Significant at 5%; ***Significant at 1%.

Table 3

The Impact of R&D on Share of Outsourcing Expenditures in Total Costs, 1990-2002[a]

		Random Effect Tobit		IV[c]
	Tobit	**Standard**	**Unobserved Effects[b]**	**Tobit**
Marginal effects for the probability of outsourcing	0.0921*** (0.016)	0.0418*** (0.011)	0.0288** (0.015)	0.0999*** (0.042)
Marginal effects for the expected value of outsourcing expenditures divided by costs, conditional on outsourcing being positive.	0.0133*** (0.002)	0.0057*** (0.002)	0.0039* (0.002)	0.0140** (0.006)
Observations	6825	6825	6825	3970
Number of groups		3077	3077	

[a] Dependent Variable: Value of outsourcing divided by total costs. All regressions include year dummies, industry dummies and the set of control variables described in the text. The complete regression results are shown in the Appendix. Huber-White robust standard errors are in parentheses.

[b]See Wooldridge (2002), p. 540 for a discussion of unobserved effects Tobit models. This regression includes means over time of independent variables.

[c] The instrument used for the R&D dummy is its one period lag.

* Significant at 10%. ** Significant at 5%; ***Significant at 1%.

Appendix Table A-1
Dependent Variable: The likelihood of outsourcing
Full Regression Estimates of Regressions (3), (4), (5) and (7) in Table 2

	Logit		Logit Fixed Effect		First Dif.		First Diff. & IV	
variable	dy/dx	Std. Err.	dy/dx	Std. Err.	coef.	Std. Err.	coef.	Std. Err.
RandD dummy	0.1215***	0.0178	0.0949***	0.0328	0.0663***	0.02269	0.0472	0.0617
Year dummy 1994	0.0610***	0.0160	0.0779***	0.0246				
1998	0.0986***	0.0175	0.1479***	0.0391			0.0303***	0.0111
2002	0.0472***	0.0188	0.1092***	0.0357				
sales	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
product_standard	-0.0215	0.0175	-0.0486	0.0351	-0.0292	0.0238	-0.0364	0.0291
foreign_own	-0.045**	0.0221	-0.0022	0.0486	0.0169	0.0371	-0.0116	0.0450
export_propensity	0.0275	0.0360	0.1587*	0.0850	0.1162*	0.0618	0.0320	0.0774
If using computer digital machine tools	0.0296*	0.0153	0.0161	0.0240	0.0018	0.0177	-0.0169	0.0217
If using robotic	0.0360*	0.0195	0.0029	0.0298	0.0071	0.0220	-0.0074	0.0254
age	0.0024***	0.0010						
age^2	-0.0000*	0.0000						
Employees: 21-50	0.0501***	0.0213	-0.0120	0.0467	0.0000	0.0000	-0.0358	0.0401
51-200	0.0457	0.0278	0.0330	0.0675			-0.0317	0.0693
201-500	0.1076***	0.0307	0.0639	0.0744			-0.0344	0.0852
501+	0.1008***	0.0393	0.0998	0.0760			-0.0756	0.1018
wage	0.0031***	0.0008	-0.0006	0.0016	-0.0011	0.0014	-0.0015	0.0016
market_expand	0.0525***	0.0154	0.0268	0.0214	0.0225	0.0161	0.0057	0.0185
market_decline	0.0329*	0.0182	0.0325	0.0254	0.0172	0.0184	0.0199	0.0234
capacity	0.0003	0.0005	0.0002	0.0007	0.0003	0.0005	0.0000	0.0007
Industry Dummies (omitted: Meat-processing)								
Foodstuffs and tobacco	0.0991	0.0661						
Drinks	-0.0882	0.0833						
Textiles	0.3663***	0.0523						
Leather and footware	0.2773***	0.0648						
Wood industry	0.2109***	0.0709						
Paper	0.1170	0.0822						
Editing and Printing	0.4187***	0.0465						
Chemical industry	0.1520**	0.0687						
Rubber and plastics	0.3051***	0.0596						
Non-metallic minerals products	0.0888	0.0699						
Iron and steel	0.0144	0.0786						
Metallic Products	0.3302***	0.0559						
Machinery and mechanical goods	0.4027***	0.0488						
Office machinery, computers, processing,	0.3665***	0.0607						
Eletrical and electronic machinery and m	0.3623***	0.0536						
Motor vehicals	0.2763***	0.0645						
Other transport material	0.3666***	0.0611						
Furniture	0.2824***	0.0629						
Other manufacturing industries	0.3832***	0.0577						

* Significant at 10%. **Significant at 5%; ***Significant at 1%

Appendix Table A-2
Dependent Variable: Share of Outsourcing Expenditures in Total Costs
Full Regression Results for Table 3

			Random Effect tobit					
	tobit		standard		unobserved effects		IV tobit	
Variable	coeff.	Std. Err.	coeff.	Std. Err.	coeff.	Std. Err.	coeff.	Std. Err.
RandD dummy	0.0434***	0.0074	0.0117	0.0031	0.0081	0.0042	0.0439	0.0186
Year dummy 1994	0.0137***	0.0066	0.0003	0.0029	-0.0058	0.0044	-0.017**	0.0078
1998	0.0309***	0.0069	0.0095***	0.0031	-0.0003	0.0072		
2002	0.0140*	0.0076	0.0036	0.0032	-0.0114	0.0101	-0.0257***	0.0079
sales	0.0000**	0.0000	0.0000***	0.0000	0.0000	0.0000	0.0000***	0.0000
product_standard	-0.0022	0.0077	-0.0001	0.0030	-0.0065	0.0047	-0.0053	0.0074
foreign_own	-0.0235***	0.0083	-0.0091**	0.0039	-0.0052	0.0071	-0.0323***	0.0091
export_propensity	0.0163	0.0157	0.0116*	0.0063	0.0294**	0.0114	0.0119	0.0146
If using computer digital machine tools	0.0073	0.0063	0.0018	0.0026	0.0014	0.0034	0.0071	0.0071
If using robotic	0.0105	0.0074	0.0024	0.0033	0.0001	0.0043	0.0172**	0.0083
age	0.0004	0.0003	-0.0001	0.0001	0.0010	0.0010	0.0003	0.0004
age^2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
Employees: 21-50	0.0169*	0.0096	0.0031	0.0036	0.0025	0.0037	0.0118	0.0096
51-200	0.0090	0.0117	0.0001	0.0047	-0.0006	0.0048	-0.0015	0.0119
201-500	0.0220*	0.0124	0.0025	0.0052	0.0017	0.0056	0.0017	0.0146
501+	0.0149	0.0154	-0.0050	0.0065	-0.0063	0.0073	-0.0083	0.0173
wage	0.0014***	0.0003	0.0005***	0.0001	0.0004	0.0002	0.0017***	0.0004
market_expand	0.0241***	0.0062	0.0080***	0.0026	0.0054*	0.0031	0.0154**	0.0074
market_decline	0.0093	0.0073	0.0030	0.0031	0.0060	0.0037	0.0089	0.0089
capacity	0.0000*	0.0002	0.0002**	0.0001	0.0001	0.0001	0.0006**	0.0002
Industry Dummies (omitted: Meat-processing)								
Foodstuffs and tobacco	0.0403*	0.0242	0.0118	0.0101	0.0129	0.0101	0.0154	0.0250
Drinks	0.0103	0.0362	0.0133	0.0139	0.0140	0.0140	0.0004	0.0349
Textiles	0.1795***	0.0249	0.0556***	0.0101	0.0579***	0.0101	0.1696***	0.0243
Leather and footware	0.1387***	0.0291	0.0424***	0.0121	0.0458***	0.0122	0.1152***	0.0294
Wood industry	0.1006***	0.0296	0.0280**	0.0126	0.0295**	0.0126	0.0771**	0.0314
Paper	0.0609*	0.0316	0.0090	0.0125	0.0112	0.0126	0.0581**	0.0294
Editing and Printing	0.2053***	0.0268	0.0658***	0.0112	0.0691***	0.0114	0.1804***	0.0265
Chemical industry	0.0606**	0.0247	0.0101	0.0109	0.0106	0.0110	0.0438*	0.0262
Rubber and plastics	0.1239***	0.0250	0.0265**	0.0112	0.0288**	0.0113	0.1101***	0.0266
Non-metallic minerals products	0.0468*	0.0257	0.0097	0.0107	0.0103	0.0107	0.0195	0.0260
Iron and steel	0.0197	0.0302	0.0055	0.0124	0.0077	0.0125	0.0109	0.0292
Metallic Products	0.1489***	0.0242	0.0429***	0.0104	0.0462***	0.0105	0.1153***	0.0253
Machinery and mechanical goods	0.2088***	0.0262	0.0769***	0.0108	0.0792***	0.0109	0.1783***	0.0258
Office machinery, computers, processing,	0.1530***	0.0293	0.033**	0.0142	0.0343**	0.0142	0.1349***	0.0338
Eletrical and electronic machinery and m	0.1540***	0.0251	0.0394***	0.0110	0.0405***	0.0111	0.1390***	0.0265
Motor vehicals	0.1355***	0.0263	0.0394***	0.0116	0.0423***	0.0119	0.1093***	0.0276
Other transport material	0.1905***	0.0322	0.0778***	0.0142	0.0834***	0.0145	0.1543***	0.0312
Furniture	0.1274***	0.0276	0.0333***	0.0112	0.0355***	0.0112	0.1074***	0.0271
Other manufacturing industries	0.1583***	0.0286	0.0405***	0.0133	0.0428***	0.0134	0.1110***	0.0297
Mean values of:								
RandD					0.0075	0.0062		
sales					0.0000**	0.0000		
product_standard					0.0103*	0.0062		

foreign_own					-0.0055	0.0086		
export_propensity					-0.0271**	0.0136		
If using computer digital machine tools					0.0007	0.0054		
If using robotic					0.0044	0.0067		
age					-0.0012	0.0010		
age^2					0.0000	0.0000		
employment					0.0000	0.0000		
wage					0.0001	0.0003		
market_expand					0.0079	0.0056		
market_decline					-0.0078	0.0066		
capacity					0.0002	0.0002		
constant	-0.3022***	0.0312	-0.0242**	0.0121	-0.0292*	0.0157	-0.248***	0.0320

* Significant at 10%. **Significant at 5%; ***Significant at 1%