WORKING PAPERS IN ECONOMICS

No.07/11

JONAS GADE CHRISTENSEN

PRODUCTIVITY, SIZE, AND THE DISINTEGRATION OF INDUSTRIAL PRODUCTION

Department of Economics
UNIVERSITY OF BERGEN

Productivity, Size, and the Disintegration of Industrial Production

Jonas Gade Christensen*
University of Bergen

Abstract

I develop a theoretical model of firms' sourcing decisions along the productivity dimension as in Antrás and Helpman (2004), while also incorporating task trade as in Grossman and Rossi-Hansberg (2008). The combination of these two effects permits a framework for sourcing strategies along two dimensions, which generates results where firms spread the production process of the final good over several different sources simultaneously. While reproducing the results from the aforementioned models, my model contributes refined and more detailed predictions. Testing these on firm-level data for Spanish manufacturing firms, I find strong empirical support for the model's predictions.

*I am grateful to Gaute Torsvik, Gregory Corcos and Wilhelm Kohler for their valueable comments. I would also like to thank Sigurd Birkeland for helpful discussions and suggestions.

1 Introduction

Over the last decades there has been a disintegration of industrial production, in the sense that the production chain increasingly has been split up and undertaken at separate locations outside of the firm's own production plants in the home country. This disintegration can take the form of domestic outsourcing where firms buy inputs or services from other companies in the same country, or they may acquire these from subsidiaries or from unrelated companies abroad. All of these forms of external sourcing seem to be increasing (Feenstra, 1998; Hummels et al., 2001; Antràs and Helpman, 2004, 2008 and others). There are several explanations of these trends, but global integration seems to be a common denominator for most of them. Lower transportation costs have made it more profitable to produce intermediate inputs away from the assembly plant, and the technological advances has made it possible to undertake certain accounting, engineering, and programming services anywhere in the world. Further, cheaper and easier communication has facilitated a closer contact between headquarters and production plants when it comes to sending plans, giving instructions, etc.

The international trade literature has attempted to explain this development. Departing from the explanations of Melitz (2003) and Helpman et al. (2004) of how firms sort into different forms of accessing foreign markets for final goods consumption according to productivity levels, Antràs and Helpman (2004) develop a similar framework for explaining which kind of sourcing firms will choose, depending on their productivity levels. In a model where headquarter-services are produced in-house, but manufacturing is undertaken elsewhere, they show how incomplete contracts between the final-good producers and the producers of intermediate inputs may distort the quantity and quality of inputs away from optimal levels, thus affecting variable costs of production. These distortions may be reduced with vertically integrated plants, but the fixed costs of establishing such plants are higher than the costs associated with arm's-length outsourcing. More productive firms with larger production will be able to spread these fixed costs over more units, and will thus choose to vertically integrate production.

Grossman and Helpman (2002) argue that firms make 'make or buy' decisions, based on a trade-off between transaction costs of outsourcing associated with searching and incomplete contracts, against governance costs of vertical integration. Grossman and Rossi-Hansberg (2008) extend this reasoning, while approaching the topic from a slightly different angle. They propose a theory that views the production of final goods as a series of tasks that have to be done to complete the product. They assume that tasks can be ordered according the their offshoring costs. These costs may be due to transportation, moral hazard problems, the importance of personal delivery of the tasks, or a combination of these or other reasons. The important assumption is that offshoring costs differ between tasks, and that these can be ordered in a non-decreasing manner. As with Antràs and Helpman, wages abroad are lower than in the home country, and firms will take advantage of this for all the tasks that can be undertaken cheaper abroad than at home. In their discussion, Grossman and Rossi-Hansberg focus on differences in skill intensities between industries, and the wage effects in the home country, rather than firm heterogeneity and selection into offshoring.

In this paper I combine the strength of both approaches in order to present a theoretical model that represents the actual sourcing strategies of firms more accurately than the previous literature has done. Starting from a model similar to that one of Antràs and Helpman (2004), I introduce the task-dimension from Grossman and Rossi-Hansberg (2008). This allows me to map firms' sourcing strategies along both the firms' productivity and the tasks' outsourceability, which generates predictions where firms use a combination of the available sourcing options available, both domestically and abroad. Apart from being a much more realistic representation of firms' real sourcing strategies, this mapping generates more detailed predictions than the previously mentioned literature. The model reproduces the predictions from Antràs and Helpman (2004) that only the most productive firms will source inputs from vertically integrated plants abroad through foreign direct investment (FDI), the somewhat less productive will source through arm's-length contracts with firms abroad. Even less productive firms will integrate domestically, and the least productive firms will buy inputs through arm's-length dealings with other domestic firms. However, I also show that firms will use several sourcing options simultaneously. Even the most productive firms may buy some inputs through arm's-length dealings domestically. Instead of sorting firms into four types depending on which sourcing option they use, my model predicts the intensities with which each sourcing option is used as functions of output levels, or productivity.

Firm-level data from extensive surveys among Spanish manufacturing firms permits detailed testing of the theoretical predictions. With specific questions about the intensities in the use of each of the possible sourcing options, the data contain much more detailed information on firms' sourcing strategies than other, similar data sources. The empirical testing shows that the model to a large degree seems to describe the actual relationship between output levels, productivity, and sourcing strategies.

2 The model

In this section I develop a theoretical model in an attempt to explain why different firms choose different sourcing strategies. It is important to note that I use *sourcing option* to identify the source which a firm uses to undertake a specific task, whereas by *sourcing strategy* I consider the entire mix of different sources that the firm uses in the entire production. The empirical evidence in section 3 shows that about half of the firms in my sample use more than one sourcing option, meaning that a framework that allows for combinations of several different sourcing options is necessary for a realistic discussion about firm organization.

The economic environment in the model is common in the international trade literature, and I will not dwell with equilibrium conditions in the final goods market. Products are differentiated along the lines of Dixit-Stiglitz (1977), and heterogeneous firms enter and exit as in Melitz (2003).

Consumers have demand functions,

$$U = \sum_{j=1}^{J} \mu_j \ln \left[\int_0^{N_j} q_j(i)^{\rho_j} \, di \right]^{\frac{1}{\rho_j}}, \tag{1}$$

where μ_j denotes the share of total spending the consumer uses on varieties from industry j, $q_j(i)$ is consumed quantum of variety i in industry j, and $\rho_j \epsilon (0,1)$ is the degree of product differentiation between varieties in the industry. The constant elasticity of substitution in industry j can thus be denoted $\sigma_j = \frac{1}{1-\rho_j} > 1$. This familiar setup yields inverse demand functions,

$$p_j(i) = A_j^{1-\rho_j} q_j(i)^{\rho_{j-1}}.$$

From the individual firm's point of view, A_j is taken as constant, and expresses total expenditure on varieties from industry j, over the price index for the industry.

$$A_j = \frac{\mu_j E}{\int_0^{N_j} p_j(i)^{-\frac{\rho_j}{1-\rho_j}} di},$$

where E is total expendable income, and $\int_0^{N_j} p_j(i)^{-\frac{\rho_j}{1-\rho_j}} di$ is the price index over all varieties of good j, weighted by their share in consumption from industry j. This means that revenue for the firm can be denoted

$$r_j(i) = A_j^{1-\rho_j} q_j(i)^{\rho_j}.$$

In the following I drop subscripts for industries and individual firms as it is the heterogeneity between firms within the same industry that is the main focus of this paper.

Potential entrants to the industry may enter by sinking a fixed cost of entry f_e. This permits the firm to draw its productivity level θ from a known distribution over $(0, \infty)$. The productivity level can be thought of as a total factor productivity (TFP), meaning that it works as a multiplier of the production process to determine total output. The production process is a Leontief-type technology, where a measure of different tasks all have to be undertaken in fixed amounts, here normalized to one. There are no possibilities of substitution between tasks. In the following I will use x to denote the number of times the entire production process is undertaken, which means that total output will be this production intensity, multiplied by the TFP

$$q = \theta x.$$

I assume that all tasks are undertaken outside the limits of the headquarters, but may either take place in vertically integrated plants or be bought through arm's-length outsourcing. Both sourcing options are available in the home country

N, or abroad in country S. In sum there are thus four different sourcing options for the firm:

Domestic Integrated (NI)	Domestic Outsourcing (NO)
Foreign Integrated, FDI (SI)	Foreign Outsourcing (SO)

Since all of the tasks have to be completed once in order to run the production process one time variable costs of production can be written

$$xc(s) = x \int_0^1 c_k^l(\omega)\, d\omega, \; k = \{O, I\}, \; l = \{N, S\}.$$

Each sourcing option implies some fixed costs, as well as the variable costs of production. In the case of vertically integrated plants, these fixed costs are naturally related to the investment costs of building the plant and buying the necessary machinery. For arm's-length outsourcing, the fixed costs could be searching costs to find an appropriate provider, training of workers, and testing to ensure that tasks are undertaken at an acceptable quality level. Further, I assume that any such fixed costs associated with either vertically integrated plants or outsourcing, are higher when done abroad instead of domestically. This can be explained through lack of knowledge about legal systems, local markets, language barriers, etc. In sum, I follow most of the relevant literature and assume that the fixed costs associated with sourcing strategies, f_k^l, can be ordered in the following way:[1]

$$f_I^S > f_O^S > f_I^N > f_O^N. \tag{A.1}$$

The fixed costs have to be paid for each individual task that is done within or outside the limits of the firm. This differentiates my model from Antràs and Helpman (2004), where once the fixed costs for a sourcing option are paid, the entire production process can be undertaken there. This is indeed also what happens, since their model never gives firms incentives to split the production process, as they will always choose the sourcing option with the lowest marginal costs in production, given that their production justifies the fixed costs associated with this option. There will never be incentives to split part of the production from another

[1] See for example Antrás and Helpman (2004), Helpman (2006), and others.

source with higher marginal costs, and in addition have to pay another fixed cost. My motivation for assuming that there are fixed costs associated with each task in the production process is both theoretically and empirically motivated. Firms that choose to outsource tasks will seldom find a provider that can deliver the best offer for all tasks, and may thus have to pay search costs for providers for each task. This is definitely the case when firms buy inputs from different countries, as is the case with the production of a typical "American" car, which is simultaneously produced in the United States (37%), Korea (30%), Japan (17.5%), Germany (7.5%), Taiwan (4%), Singapore (4%), the United Kingdom (2.5%), Ireland (1.5%), and Barbados (1.5%) (Antràs and Helpman, 2004). Similarly, Grossman and Rossi-Hansberg (2008) report that the production of the Boeing 787 involves 43 suppliers, producing at 135 sites worldwide.

Following the above assumptions the firms' profit maximizing problems can be written:

$$\max_{\{x,s\}} \left[A^{1-\rho}\left(\theta x\right)^{\rho} - xc\left(s\right) - f\left(x\right)\right]. \tag{2}$$

Here, the first term is the revenue term derived above, the second term expresses the variable costs, and the last term denotes the fixed cost associated with all the tasks that have to be performed. It will become clear later that the optimal sourcing strategy s is a function of x, which means that both the variable costs, and the "fixed" costs depend on the equilibrium production intensity. The first order conditions wrt x can thus be written:

$$\rho A^{1-\rho}\theta^{\rho}x^{*\rho-1} - \left.\frac{\partial c\left(x\right)}{\partial x}\right|_{x=x^*} x - c\left(x^*\right) - \left.\frac{\partial f\left(x\right)}{\partial x}\right|_{x=x^*} = 0,$$

where $\frac{\partial c(x)}{\partial x} = \frac{\partial c(s)}{\partial s}\frac{\partial s}{\partial x}$, which relation will become clear at a later stage. This condition yields a specific expression for neither production intensity x^*, nor output θx^*. It does, however, implicitly define these identities, and I assume that firms are able to derive their optimal production levels from this condition. It can also be shown that as long as the second-order conditions for profit maximization hold, more productive firms will produce at a higher intensity, $\frac{\partial x}{\partial \theta} > 0$, and thus also $\frac{\partial q}{\partial \theta} > 0$. The proof of this is relegated to Appendix A2. This shows that although the cost structure in the model is different from the Melitz model, the key results come through. It also means that all the qualitative relations between production intensity x and sourcing strategies that I discuss below will also hold for productivity and sourcing strategies.

Knowing its optimal production intensity, the firm will chose a sourcing strategy in order to maximize profits. In the following I will make the simplifying assumption that the impact of an individual task on the optimal production is negligible, so that firms will disregard the output effect from switching from one sourcing option to another for a given task.

As discussed above, all tasks can potentially be undertaken either in the north or in the south. The variable costs of production in each place will naturally depend on wages in the respective countries. I assume that wages are lower in the south than in the north, $w^N > w^S$, as otherwise no firm will ever chose to have any tasks done abroad. If the difference in fixed costs between vertical integration and outsourcing is not significantly different between home and abroad, it will also be the case that $w^N \left(f_I^S - f_O^S\right) > w^S \left(f_I^N - f_O^N\right)$, which is a condition I will assume to hold for simplicity throughout the paper.

All of a measure of tasks must be undertaken in order produce final products. These tasks can be ordered according to their degree of outsourceability.[2] The intuition behind this is that tasks can be ordered according to how standardized, or 'codifiable,' they are. Some tasks are easier to define in writing, thus making it easier both to give clear instructions to workers in spite the lack of physical proximity, and lowering the possibility of moral hazard-related problems due to contract incompleteness.[3] I denote the *ad valorem* costs of producing outside the limits of the firm by $t(\omega)$. The total costs associated with each sourcing strategy

[2] Note that this differs from Grossman and Rossi-Hansberg (2008), who assume that tasks differ in terms of offshoreability instead of outsourceability.

[3] I will not specify the bargaining problem from incomplete contracts in this paper. Rather, I just assume that tasks can be ordered according to their degree of outsourceability. For a more specific discussion on the form of moral hazard and bargaining in the outsourcing literature, see for example Antràs (2003; 2005), Antràs and Helpman (2004; 2007), and Acemoglu et al. (2007).

for a given task ω can be written:

$$\begin{aligned} C_O^N &= t(\omega) w^N x + f_O^N \\ C_I^N &= w^N x + f_I^N \\ C_O^S &= t(\omega) w^S x + f_O^S \\ C_I^S &= w^S x + f_I^S \end{aligned}$$

The optimal sourcing strategy will thus be defined by

$$s^*(\omega; x^*) = \arg\min \left\{ c_k^l x^* + f_k^l \right\}, \qquad (3)$$

which states that for any level of outsourceability ω and optimal production intensity, the firm will choose the cheapest available sourcing option. Since there are no externalities in production between the tasks, the firm will naturally chose the sourcing strategy for each task that minimizes total costs for that specific task individually, without taking sourcing decisions for other tasks into consideration. I can thus solve for the optimal sourcing strategy for a firm with total production $x^*(\theta)$ through pairwise comparisons between all possible sourcing options for all tasks.

When production is close to zero, domestic outsourcing will always be the preferred source for all tasks, since this is the option with the lowest fixed costs. However, as production increases, sourcing options with lower variable costs may justify paying higher fixed costs. These differences in variable costs means that for each pair of sourcing options, there will be a cutoff value for $\omega = \omega'$ below which one sourcing option will be preferred over the other for all tasks $\omega \epsilon [0, \omega')$, and contrary for all tasks, ω, above this level.[4] Compare for example, the costs of outsourcing domestically (NO) with those of vertically integrating domestically (NI). With fixed costs ranked as assumed above, it is easy to see that for low values of $t(\omega)$ NO is preferable to NI. As the costs of outsourcing increase, however, this order will be reversed. Since $t(\omega)$ is monotonically increasing in ω, there will be

[4] The one exception to this is the comparison between domestic and foreign vertical integration, as these are both independent of outsourceability. There are still differences in marginal costs between these, but the preferred option will solely be determined by the production quantity.

a value $\omega = \omega_{NONI}$ for which the firm will be indifferent between choosing NO or NI.[5] This value is implicitly defined by:

$$
\begin{aligned}
t\left(\omega_{NONI}\right) w^N x + f_O^N &= w^N x + f_I^N \\
t\left(\omega_{NONI}\right) &= 1 + \frac{f_I^N - f_O^N}{w^N x}
\end{aligned}
$$

Similarly, cutoff-values for ω for all pairwise rankings can be derived to be:[6]

$$
\begin{aligned}
t\left(\omega_{NONI}\right) &= 1 + \frac{f_I^N - f_O^N}{w^N x} \\
t\left(\omega_{SONI}\right) &= \frac{w^N}{w^S} - \frac{f_O^S - f_I^N}{w^S x} \\
t\left(\omega_{SOSI}\right) &= 1 + \frac{f_I^S - f_O^S}{w^S x} \\
t\left(\omega_{NOSI}\right) &= \frac{w^S}{w^N} + \frac{f_I^S - f_O^N}{w^N x} \\
t\left(\omega_{NOSO}\right) &= \frac{f_O^S - f_O^N}{\left(w^N - w^S\right) x}
\end{aligned}
$$

From these conditions one can also see that the cutoff outsourceability levels are dependent on x. This means that the optimal sourcing strategy for larger firms will be different from that of smaller firms. This is quite intuitive, as larger firms will benefit more from reductions in variable costs, as there are more units over which the fixed costs can be spread. The story here is analogous to the exporting models in Melitz (2003) and Helpman et al. (2004), where large firms can spread fixed costs over more units, and as such will opt for strategies with lower variable costs than smaller firms will. While the aforementioned papers study market access strategies for final goods, the story is similar for trade and investments in tasks, or intermediate inputs.

So far I have only determined conditions for pairwise comparisons of sourcing options. In order to get a complete mapping for which sourcing strategies a firm will opt for given production x, I need to determine simultaneous preference order-

[5] I denote these indifference loci of ω such that for $\omega < \omega_{ab} \rightarrow a \succ b$.

[6] The ranking of domestic integration (NI) versus foreign integration (SI) is naturally independent of ω, as ω indicate the outsourceability of a given task.

ings between all sourcing options. Since all the cutoff-values of ω are functions of x, it is possible to determine for which production levels a given cutoff ω is larger than another cutoff, i.e. when it is the case that for example $\omega_{NONI} > \omega_{NOSI}$.

$$\omega_{NONI} \geq \omega_{NOSI} \Leftrightarrow t\left(\omega_{NONI}\right) \geq t\left(\omega_{NOSI}\right) \Leftrightarrow 1 + \frac{f_I^N - f_O^N}{w^N x} \geq \frac{w^S}{w^N} + \frac{f_I^S - f_O^N}{w^N x}.$$

There exists a value for x that ensures that the above holds with equality:

$$\omega_{NONI} \geq \omega_{NOSI} \Leftrightarrow x \geq \frac{f_I^S - f_I^N}{w^N - w^S} = x_{NOSINONI}.$$

This means that for firms with optimal production intensity $x^* > x_{NOSINONI}$, the cutoff point ω_{NONI} comes for a higher value of ω than for ω_{NOSI}.[7] Similarly all pairwise comparisons of these cutoff-values can be expressed as functions of x. These sets of pairwise comparisons let me construct a complete mapping of sourcing strategies for firms. In the following I derive the determinants of the sourcing strategies for small firms as an illustrative example. A more complete presentation of this process can be found in Appendix A3.

It turns out that many of the cutoff values of x coincide, and as a result, there are five categories of firms, according to size. In each category the ranking of cutoff levels for ω defines which sourcing option will be preferred for different intervals over ω. Take for example the case of the smallest firms. For these firms it will be the case that

$$\omega_{SONI} < \omega_{NONI} < \omega_{SOSI} < \omega_{NOSI} < \omega_{NOSO}.$$

This means that for the tasks that are cheapest to outsource, $\omega \epsilon \left[0, \omega_{NISO}\right)$, the result of all pairwise comparisons of sourcing options will be

$$SO \succ NI,\ NO \succ NI,\ SO \succ SI,\ NO \succ SI,\ NO \succ SO,$$

which unambiguously shows that NO, outsourcing domestically, is preferred to any other sourcing option. Doing this for all the intervals of ω it turns out that this option is the Condorcet-winner until $\omega = \omega_{NONI}$. This comes as no surprise,

[7]Similarly to the ω-loci, I denote the cutoff production intensities such that $x < x_{ab} \rightarrow \omega_a > \omega_b$.

as this is exactly the cutoff-value of ω where NI becomes cheaper than NO. For this firm-size category NI stays the cheapest sourcing option for all tasks with $\omega \geq \omega_{NONI}$. The sourcing strategy for the smallest firms will thus be

$$s(x) = \begin{cases} \left\{\begin{smallmatrix} NO \text{ for } \omega\epsilon[0,\omega_{NONI}) \\ NI \text{ for } \omega\epsilon[\omega_{NONI},1] \end{smallmatrix}\right. & \text{if} \quad \omega_{NONI}\epsilon\,[0,1] \\ NI \text{ for } \omega\epsilon\,[0,1] & \text{if} \quad \omega_{NONI} < 0 \\ NO \text{ for } \omega\epsilon\,[0,1] & \text{if} \quad \omega_{NONI} > 1 \end{cases}.$$

Note again, however, that ω_{NONI} is a function of x, meaning that the relative intensity between the two sourcing options will differ among firms within the category. Since $t(\omega_{NONI}) = 1 + \frac{f_I^N - f_O^N}{w^N x}$ is falling in x, larger firms within the category will undertake relatively more tasks in vertically integrated plants than the smaller firms will. The two last sourcing strategies in the expression above are corner solutions where firms will choose one sourcing option for all values of x^*.[8] In the rest of this section I will focus mainly on the internal solutions to simplify notation. Where relevant, corner solutions will be discussed in Appendix A1.

Repeating this exercise for all other categories of firm sizes I can define the cutoff-sizes of firms that divide firms in size-categories in increasing order as follows:

Category	Production intensity
1	$x_{NOSONOSI} > x^*$
2	$x_{NOSOSONI} > x^* > x_{NOSONOSI}$
3	$x_{SONINOSI} > x^* > x_{NOSOSONI}$
4	$x_{NISI} > x^* > x_{SONINOSI}$
5	$x^* > x_{NISI}$

Within each such category the ranking of the relevant cutoff points for ω are clearly determined. This permits a mapping of sourcing strategies along the dimensions of optimal production intensity, $x^*(\theta)$, and the cost of outsourcing, $t(\omega)$, which is depicted in Figure 1. In the figure the categories are shown, separated by the

[8] This is only the case for sufficiently low levels of x. This will become apparent later in this section.

vertical dotted lines.

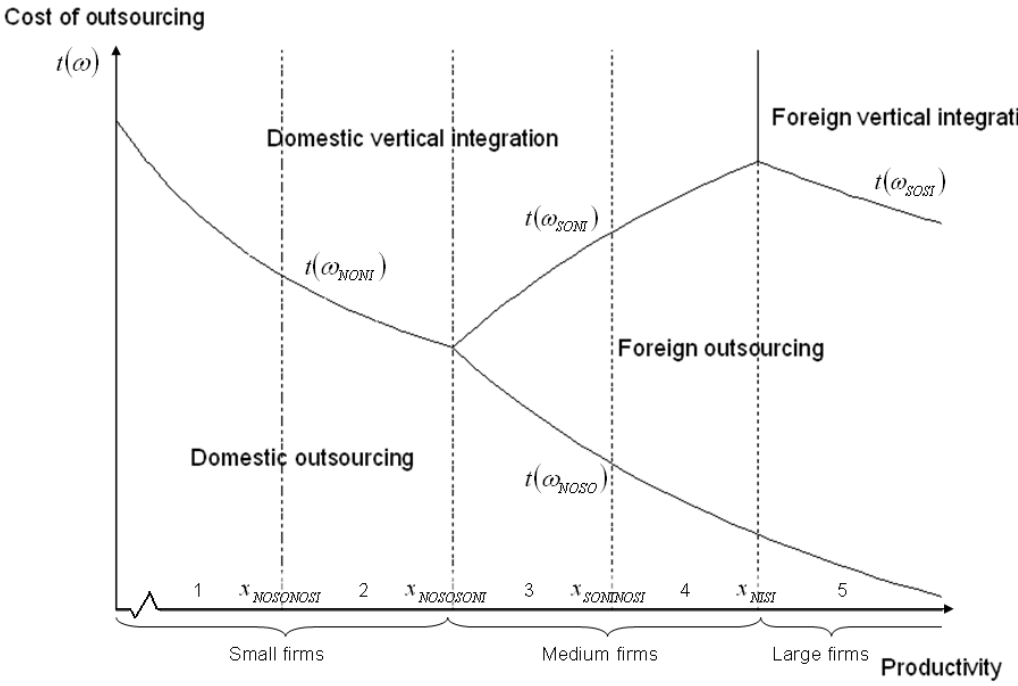

Figure 1: Sourcing strategies and productivity

It turns out that the two categories with the smallest firms (1 and 2), and the two categories with intermediate firms (3 and 4) are qualitatively the same, and these can be merged, so that I end up with three size categories of firms; small, medium, and large. The figure is thus completely determined by the following loci: $t(\omega_{NONI})$, $t(\omega_{NOSO})$, $t(\omega_{SONI})$, $t(\omega_{SOSI})$, $x_{NOSOSONI}$, and x_{NISI}. The critical size, $x_{NOSOSONI}$, determines which firms engage in international sourcing and which do not. Below this value, $t(\omega_{NONI})$ determines the share of tasks that are undertaken in vertically integrated plants, and which are outsourced domestically. For firm sizes between $x_{NOSOSONI}$ and x_{NISI} the locus $t(\omega_{NOSO})$ determines which tasks are outsourced domestically, which will be the tasks with $\omega < \omega_{NOSO}$. For these same firms, tasks with $\omega_{NOSO} < \omega < \omega_{SONI}$ are outsourced in the foreign country, and the tasks $\omega_{SONI} < \omega$ are undertaken in vertically integrated plants domestically. The largest firms, with production $x_{NISI} < x$, will again outsource tasks $\omega < \omega_{NOSO}$ domestically and tasks $\omega_{NOSO} < \omega < \omega_{SONI}$ from the foreign country. These firms, however, will undertake the tasks $\omega_{SOSI} < \omega$ in vertically integrated plants abroad through FDI.

The above discussion means that within these categories the firms will choose their sourcing strategies from the following options:

Category	Sourcing strategies
Small	$NO,\ NI$
Medium	$NO,\ SO,\ NI$
Large	$NO,\ SO,\ SI$

Qualitatively there are two demarcation criteria that distinguish the categories. The first one is that small firms do not engage in international sourcing; they undertake all tasks domestically. The second one is that among the firms that do engage in international sourcing, only the largest choose to produce in integrated subsidiaries through FDI, whereas if the medium firms choose vertical integration, they will do so domestically. In other words, the model predicts that no firms will simultaneously undertake tasks in vertically integrated plants domestically and internationally. The reason for this is that I have assumed no inefficiencies in contractibility etc. for vertically integrated plants, so if a firm has a sufficiently large production and vertical integration abroad is cheaper than vertical integration domestically for one task, this will hold for all tasks. This assumption could be softened by introducing some distance costs associated with foreign production $\tau(\omega)$, as in Grossman and Rossi-Hansberg (2008), such that $c_O^S = t(\omega)\,\tau(\omega)\,w^s$ and $c_I^S = \tau(\omega)\,w^s$. This would require either an assumption that the ordering of tasks is such that both $t(\omega)$ and $\tau(\omega)$ are monotonically increasing, or introducing a third dimension along the $\tau(\omega)$-axis. For simplicity, and in order to be able to map sourcing strategies in a two-dimensional figure, however, I choose to stick to the assumption that $\tau = 1 \perp \omega$.

The variable costs of production for small, medium, and large firms, respectively, can be expressed as $\frac{c(x^*)}{\theta}$, and is determined as follows:[9]

$$\begin{array}{rl} c^s(x^*) = & \int_0^{\omega_{NONI}} t(\omega)\, w^N d\omega + \int_{\omega_{NONI}}^1 w^N d\omega \\ c^m(x^*) = & \int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega + \int_{\omega_{NOSO}}^{\omega_{SONI}} t(\omega)\, w^S d\omega + \int_{\omega_{SONI}}^1 w^N d\omega \\ c^l(x^*) = & \int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega + \int_{\omega_{NOSO}}^{\omega_{SOSI}} t(\omega)\, w^S d\omega + \int_{\omega_{SOSI}}^1 w^S d\omega \end{array} .$$

From the definitions of the $t(\omega)$-loci it is clear that $c^l \leq c^m \leq c^s$. (Proof is in Appendix A1.) This implies that there are two effects that make more productive firms larger than less productive firms. First, there is the direct effect that more productive firms will produce each unit of output at a lower price, and thus be more competitive and sell more units. They will also undertake the production process more times than will less productive firms. This second effect ensures that the more productive firms are able to choose cheaper sourcing strategies, which again lowers their costs per run of the production process, and thus also per unit costs, and further increases the size of more productive firms. The sum of these two effects would lead to a skewed distribution of firm sizes, with a longer right tail in the distribution than in the initial productivity distribution, even if the *ex ante* productivity distribution should be uniform.

The model predicts that the least productive firms will only engage in domestic sourcing, whereas only the most productive firms will do FDI and source from vertically integrated firms abroad. Firms with intermediate productivity levels will outsource to the foreign country, but not do FDI. This replicates the results from Antràs and Helpman (2004). However, the main contribution of this model is in the details. Whereas it reproduces the findings of previous models, it also allows firms to choose sourcing strategies involving several different sourcing options. This again generates predictions on the relative intensities of each sourcing option as functions of firm productivity. Looking at each sourcing option individually, the following predictions can be derived from the model:

Prediction 1: *Outsourcing in the north (NO) is a decreasing function of productivity.*

This is easily seen from the fact that both $\frac{\partial t(\omega_{NONI})}{\partial x} = -\frac{f_I^N - f_O^N}{w^N x^2} < 0$ and

[9] For $0 < \omega_{NONI},\ \omega_{NOSO},\ \omega_{SONI},\ \omega_{SOSI} < 1$.

$\frac{\partial t(\omega_{NOSO})}{\partial x} = -\frac{f_O^S - f_O^N}{(w^N - w^s)x^2} < 0$, which means that also $\frac{\partial t(\omega_{NONI})}{\partial \theta} < 0$ and $\frac{\partial t(\omega_{NOSO})}{\partial \theta} < 0$, and NO is decreasing in θ for all $\theta \in (0, \infty)$.

Prediction 2: *Vertical integration in the north (NI) is initially increasing, and then decreasing in productivity.*

For $x^* < x_{NOSOSONI}$ vertical integration in the north is equal to $1 - \omega_{NONI}$. Since $\frac{\partial t(\omega_{NONI})}{\partial \theta} < 0$, it must be that $\frac{\partial (1-\omega_{NONI})}{\partial \theta} > 0$, and NI is increasing in productivity in this area. For $x_{NOSOSONI} < x^* < x_{NISI}$ NI is determined by $1 - \omega_{SONI}$. $\frac{\partial t(\omega_{SONI})}{\partial x} = \frac{f_O^S - f_I^N}{w^S x^2} > 0$, which implies that $\frac{\partial t(\omega_{SONI})}{\partial \theta} > 0$, and NI is decreasing in this interval. For higher levels of productivity there will be no use of NI.

Prediction 3: *Outsourcing in the south (SO) is (initially) increasing in productivity.*

For productivities that give the interval $x_{NOSOSONI} < x^* < x_{NISI}$ the share of foreign outsourcing in a firm is equal to $\omega_{SONI} - \omega_{NOSO}$. We have already seen that $\frac{\partial t(\omega_{SONI})}{\partial \theta} > 0$ and $\frac{\partial t(\omega_{NOSO})}{\partial \theta} < 0$, implying that $\frac{\partial (\omega_{SONI} - \omega_{NOSO})}{\partial \theta} > 0$, but this would be irrelevant if $\omega_{SONI} - \omega_{NOSO} < 0$. It follows from the monotonicity of $t(\omega)$ that

$$\omega_{SONI} - \omega_{NOSO} > 0 \Leftrightarrow t(\omega_{SONI}) - t(\omega_{NOSO}) > 0.$$

Inserting the minimum x^*, $x_{NOSOSONI} = \frac{w^N\left(f_O^S - f_I^N\right) + w^S\left(f_I^N - f_O^N\right)}{w^N(w^N - w^S)}$ in this interval, yields $t(\omega_{SONI}) - t(\omega_{NOSO}) = 0$, meaning that the share of tasks that are offshored to the foreign country starts at 0 and then increases monotonically in the interval up to $x^* = x_{NISI}$. From this point on, the effect on SO is ambiguous. Both $\frac{\partial t(\omega_{NOSO})}{\partial \theta} < 0$ and $\frac{\partial t(\omega_{SOSI})}{\partial \theta} < 0$, but whether they fall at an equal pace, or whether one falls more rapidly than the other, depends on the shape of $t(\cdot)$. Without assuming anything about this function, the prediction is thus that the relationship between productivity and SO will initially be positive, but potentially be non-linear.

Prediction 4: *Vertical integration in the south (SI) is increasing in productivity.*

This follows simply from the fact that for firms with productivity such that $x^* > x_{NISI}$, which are the only firms that will engage in SI, the share of tasks undertaken in vertically integrated plants abroad will be $1-\omega_{SOSI}$. Since $\frac{\partial t(\omega_{SOSI})}{\partial x} = -\frac{f_I^S - f_O^S}{w^S x^2} < 0 \Longrightarrow \frac{\partial t(\omega_{SOSI})}{\partial \theta} < 0$, it must be that $\frac{\partial (1-\omega_{SOSI})}{\partial \theta} > 0$ for these firms.

The empirical literature has often focused on offshoring, as this has been easier to obtain data for, than for each sourcing option separately. Grouping SO and SI together shows that offshoring should also be clearly increasing in both production intensity and productivity of firms. One could also group NI and SI to study whether more productive firms or firms with higher output levels would use more or less vertically integrated plants to produce intermediate inputs. Here the model has no clear predictions, as this relationship seems to be highly non-linear, but with no apparent dominating trend. If the distribution function from which the firms draw productivity is somewhat Pareto-shaped, as has been documented by empirical studies (Del Gatto et al., 2007), the small and medium sized firms would likely dominate the total effect on the use of vertical integration.[10] Taking this into consideration, the use of vertical integration as a function of production intensity or productivity should resemble the relationship between vertical integration in the north and the same independent variables.

These new and more detailed predictions, compared to previous models, will be the main focus of my empirical investigation in section 3.

2.1 Comparative statics

This mapping of sourcing strategies in a $(x^*(\theta), t(\omega))$-diagram allows for some comparative static analysis. In the following I will show what the model predicts for changes in wages in the north, w^N.

There is a growing literature on the effects of offshoring on domestic wages. The earliest arguments were that in developed, capital- and skilled labor-rich countries firms would offshore tasks that are intensive in the use of (low-skilled) labor, thus reducing demand for (low-skilled) labor, and hence also wages (see for example

[10] A sneak peek at the data reveals that around 85% of the firms in the sample are categorized as small or medium when using the demarcation criteria from the model, indicating that these firms should indeed dominate the overall effect.

Feenstra and Hanson, 1996; 1999).[11] Others argued that the increased wage gap between high- and low-skilled labor was driven by competition from low-wage countries, as well as technological advances (Leamer, 1996; Autor et al. 1998). Later contributions have shown how such offshoring may actually increase wages, through either productivity gains (Girma and Görg, 2004; Grossman and Rossi-Hansberg, 2008; and others), or through increased bargaining power for labor unions (Lommerud et al., 2009). The net effect on wages from offshoring thus depends heavily on which factors dominate. In this paper I will not go into this debate, but only show how a change in wages in the north will affect sourcing strategies for firms. This will then enable me to comment on possible feedback-effects if offshoring indeed changes the home country wages. If changes in offshoring lead to changing wages, this should over time affect the firms' optimal sourcing strategies. If it is indeed the case that increased offshoring will lead to increased wages, whereas increasing wages leads to increased offshoring, then a small initial change could potentially lead to large total effects.

As discussed above, the choice of sourcing strategies as a function of firm size is completely determined by $t\left(\omega_{NONI}\right)$, $t\left(\omega_{NOSO}\right)$, $t\left(\omega_{SONI}\right)$, $t\left(\omega_{SOSI}\right)$, $x_{NOSOSONI}$, and x_{NISI}. The effects of a change in northern wages on these are

$$
\begin{aligned}
\frac{\partial t\left(\omega_{NONI}\right)}{\partial w^N} &= -\frac{f_I^N - f_O^N}{\left(w^N\right)^2 x} < 0 \\
\frac{\partial t\left(\omega_{NOSO}\right)}{\partial w^N} &= -\frac{f_O^S - f_O^N}{\left(w^N - w^S\right)^2 x} < 0 \\
\frac{\partial t\left(\omega_{SONI}\right)}{\partial w^N} &= \frac{1}{w_s} > 0 \\
\frac{\partial t\left(\omega_{SOSI}\right)}{\partial w^N} &= 0 \\
\frac{\partial x_{NOSOSONI}}{\partial w^N} &= \frac{\left(w^N - w^S\right)^2\left(f_I^N - f_O^N\right) - \left(w^N\right)^2\left(f_O^S - f_O^N\right)}{\left(w^N - w^S\right)^2\left(w^N\right)^2} < 0 \\
\frac{\partial x_{NISI}}{\partial w^N} &= -\frac{f_I^S - f_I^N}{\left(w^N - w^S\right)^2} < 0.
\end{aligned}
$$

[11] Offshoring is here defined as undertaking tasks abroad, and thus includes both outsourcing and vertical FDI in the south in my model.

The changes are depicted graphically in Figure 2.

This clearly shows that an increase in wages in the north will lead to an unambiguous increase in foreign sourcing if the distribution of firm sizes remains constant. This is not at all surprising, but it illustrates an important point: if it is the case that offshoring indeed increases wage levels at home, this should lead to a circular effect where firms get increased incentives to seek foreign sourcing options. If this self-reinforcing effect is strong enough, a small increase in northern wages could ultimately lead to all tasks being offshored. This does not sound like a likely outcome, however, and could possibly indicate that if offshoring leads to increased wages, this may only be for certain degrees of offshoring. This is exactly what is predicted in Kohler and Wrona (2010).

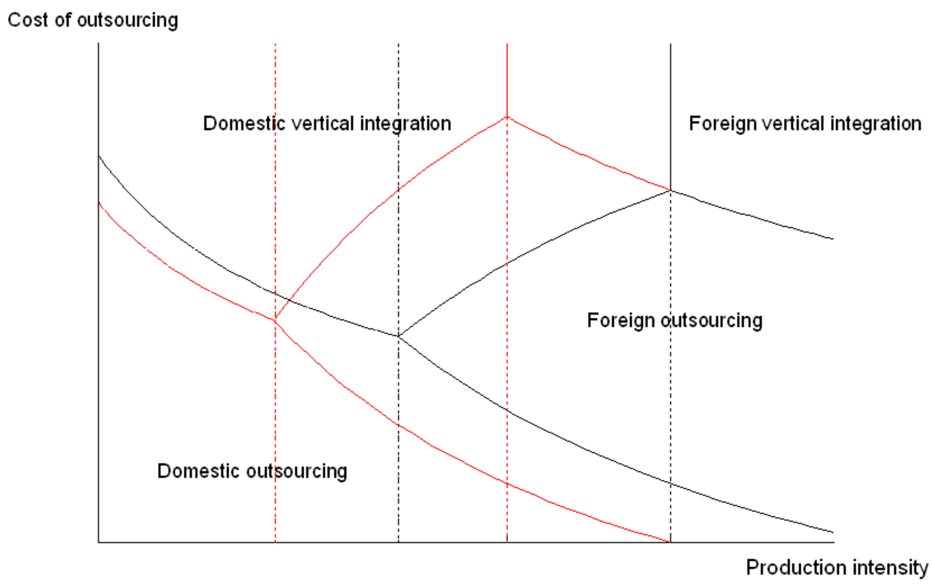

Figure 2: Increase in the wages in the north

3 Data and empirical strategy

In this section of the paper I will test some of the predictions generated in the theoretical model. Due to the nature of the data, not all predictions can be tested, and the ones I do test should not be interpreted as causal mechanisms. It is however a necessary, although not sufficient, condition for the validity of the theoretical model that the testable predictions be reflected in the data. Should this be the case, then it would be an indication that the model cannot readily be seen as falsified by the empirical testing, and would as such indicate some support of the model.

The relationship between productivity and sourcing strategies has been tested in the empirical literature before. Nunn and Trefler (2008) test the predictions from Antràs (2003) and Antràs and Helpman (2004) on intra-firm trade, using data on U.S. firms' within-industry imports from foreign affiliates, and find some support for their predictions that intra-firm trade should be higher among firms that are intensive in their use of headquarter services. The same is also the case for firms that are skill- and capital-intensive. Corcos et al. (2008) refine this research using French firm-level data, and include TFP measures as an explanatory variable. Their study shows that also more productive firms are more likely to source inputs through intra-firm international imports. Both of these studies rely on import data to construct their sourcing variables, which may be an imprecise measure of sourcing, as it is hard to distinguish which imports are actually intermediate inputs in production. One study that avoids this problem is Tomiura (2007). Using survey data on Japanese firms, he has information directly from firms on "whether they contract out manufacturing or processing tasks to other firms overseas," a direct dummy for SO in my model: foreign outsourcing. His findings indicate that firms that outsource to foreign countries are less productive than firms that do FDI, but more productive than domestic firms. These findings compare directly to the "predicted firm sizes" from my model, and also show the same productivity ordering that my model predicts. Federico (2010) uses Italian survey data that includes information on all four sourcing options that I use in my model. Measuring the productivity premium for firms that use the different sourcing options, he concludes that firms that choose foreign integration are the most productive, and the ones choosing domestic outsourcing are the least productive. However, contrary to the predictions in my model, he claims that domestic integration is chosen by medium-high productivity firms, whereas medium-low productivity firms prefer foreign outsourcing. Kohler and Smolka (2009) use the same

Spanish survey data as I use in this paper to study the connection between firm productivity and sourcing behavior. As I will come back to later in this chapter, these data contain information about the intensity with which all four sourcing options are used, as well as data that distinguishes firms that are headquarters from the ones that themselves are subsidiaries of foreign firms. Interestingly, their study concludes that the unrestricted sample, when "non-headquarter" firms are included, gives results that are in line with those in Federico (2010). However, when studying only firms that are true headquarters, and as such assumed to have complete discretion over sourcing strategies, the productivity ordering between firms that outsource to the foreign country and those that integrate domestically is reversed and in accordance with the predictions from my model.

The data I use are acquired from the annual business survey from Fundación SEPI.[12] The survey covers about 2,000 firms with more than 10 employees annually, and report data for individual firms, and not corporate groups. All firms with more than 200 employees are invited to participate, whereas a random sample of about 5% of firms with 10-200 employees are asked.[13] This means that large firms are somewhat overrepresented in the sample, something I try to control for when possible and necessary.

The main advantages of these data, compared to other firm-level data, is the detail of the information that it contains, both of the main variables of interest and of some important control variables. As discussed above, many empirical investigations of offshoring use imports in the same SIC category as a proxy for offshoring. In the data used here the firms answer direct questions about the percentage of intermediate inputs they buy from other, related or unrelated firms, domestically and abroad. These four variables thus correspond directly to the four sourcing options described in my theoretical model. Unfortunately these questions have only been included in the survey for the years 2006-2008, and with

[12] The survey "Encuesta sobre estrategias empresariales" is conducted by Fundación Sociedad Estatal de Participaciones Industriales. See http://www.funep.es/esee/en/einfo_que_es.asp for more information about the foundation and the survey.

[13] Starting from the initial sample from 1990, SEPI has included all newly incorporated firms with more than 200 employees, and a randomly selected sample of about 5% of the newly incorporated firms with 10-200 employees. As such the large firms are overrepresented in the data, but within each group careful measures are taken to ensure the representativeness of the data. Average response rate for 1990-2008 is an impressive 91.97%.

little variation in sourcing strategies over such a short time period, the data do not permit the use of panel data techniques in order to perform better tests for causality, as well as selection- and learning-effects of different sourcing strategies. With the continued collection of these variables though, such investigations will become possible in the near future. The data do however permit the use of lagged values for productivity, as measured productivity could potentially be affected by sourcing behavior. The results do not seem to change with either one- or two-year lags, and only the results from running the unlagged variables are reported here. In total my data set is a relatively balanced panel that includes information on 4,629 firms from 1999 to 2008. As I only have information on my main variables of interest since 2006, the results reported in this section are from cross-sectional analysis for individual years between 2006-2008. The results reported here are from 2007, but all three years show similar results. The longer time-series are used in estimating total factor productivity for the individual firms. For a more thorough discussion of the data, see Kohler and Smolka (2009).

Making dummies for the use of each sourcing option, I get four not mutually exclusive categories. The summary statistics show (with large firms excluded in parentheses) that 4.2% (4.8%) of the firms in the survey buy no intermediate inputs through any of the sourcing options, 92.4% (93.0%) outsource domestically, 43.1% (34.6%) outsource from other countries, and 15.4% (8.4%) and 10.4% (3.7%) buy inputs from vertically integrated plants in Spain and other countries, respectively. Around 47.8% (37.4%) of the firms in the sample source from more than one of the four options every year. These values show that almost all firms buy some intermediate inputs from other firms, and also shows models that predict that firms will source all their input from the same provider are in discordance with the empirical observations.

I will let the empirical part of this study follow the theoretical model as closely as possible. The descriptive statistics in Table 1 are thus divided by predicted size according to the size definitions from the model. If a firm only buys intermediate inputs from domestic sources, it is classified as small. Firms that do buy inputs through arm's-length dealings with independent firms abroad (SO), but do not undertake FDI and produce in vertically integrated plants abroad, are categorized as medium, and finally firms that have vertically integrated plants abroad are classified as large. The summary statistics for each of these categories are shown below.

Predicted size	Output	Productivity	Export status	Similar product	Capital intensity
Small	39.31	3.84	0.45	0.03	18.02
Medium	71.20	3.91	0.81	0.08	24.14
Large	339.72	4.16	0.97	0.26	33.65
Total	81.59	3.90	0.62	0.07	21.75

Predicted size	R&D intensity	Capacity utilization	Employees	N
Small	0.31	83.20	127	1,006
Medium	0.60	82.78	222	691
Large	1.86	82.47	691	209
Total	0.57	83.08	218	2,006

Table 1: Descriptive statistics

Table 1 summarizes the main variables I will focus on in this section, for each size group and for the sample average. The first thing we notice is that OUTPUT, defined as the sum of sales plus the variation in inventory, in millions of Euros, corresponds well to the predicted size categories from the model, with the 'medium' firms producing a little less than the average output in the sample, while the 'small' firms produce around half, and the 'large' firms produce more than four times the average output. As predicted by the model, the PRODUCTIVITY is also increasing in the size categories. This variable is generated with the Olley and Pakes (1996) method, which has become the favored method of estimating total factor productivity in the economic literature, thanks to its correction for endogeneity issues related to productivity shocks and selection in the exit decisions. Among the important control variables when studying sourcing strategies and productivity I have also included EXPORT STATUS, which is a dummy for whether the firm is an exporter or not. This variable shows a very similar pattern to that of productivity, which is the familiar "Melitz-result" (2003), that more productive firms will become exporters whereas less productive firms will produce only for the domestic market. The next variable, SIMILAR PRODUCT, is a dummy for whether the main foreign affiliate of the firm (if it has one) produces a similar product, or in other words if the group has undertaken horizontal FDI. The rationale for including this variable is that if a firm has several production plants producing the same product, the total production will be larger than that reported only by the domestic firm, and according to the forces at work in the theoretical model, it will thus have more units over which to spread the fixed costs, and stronger incentives to choose a sourcing option with lower marginal costs. In total only 6% of the firms produce a similar product to their main affiliate, but in the large firm category, 25% of the firms do, indicating that this is a prominent feature among the largest firms. The next two variables show that the larger firms both have higher CAPITAL INTENSITY and R&D INTENSITY than the smaller firms. I have also included the firms' degree of CAPACITY UTILIZATION. This does not seem to vary systematically across the different size categories, but could have some explanatory power over sourcing options. Specifically one could expect that firms would increase their domestic outsourcing when capacity utilization is very high, as this could be the cheapest short-term solution to cover for example a temporary demand shock. Finally, Table 1 shows that the predicted sizes correspond to the actual sizes when measured in the number of EMPLOYEES.

3.1 Results

The fit of predicted size categories according to the model, and real size categories, measured in total production, is reported in Table 2.

Predicted size		Actual company size 1	2	3	4	5	Total
Small		346	275	229	149	107	1 106
		31.28	24.86	20.71	13.47	9.67	100.00
Medium		54	122	157	194	164	691
		7.81	17.66	22.72	28.08	23.37	100.00
Large		0	3	15	60	131	209
		0.00	1.44	7.18	28.71	62.68	100.00
Total		400	400	401	403	402	2 006
		19.94	19.94	19.99	20.09	20.04	100.00

Table 2: Predicted size versus actual firm size

The actual sizes are divided into quintiles when firms are sorted according to total value of production. The second row for each predicted size category shows the percentage of the firms in this category that fits in each of the actual size categories. Reading these shares horizontally, we see that the firms that are predicted to be 'small' according to the theoretical model are predominantly among the small firms when sorted by actual production as well. In fact, 67% of the firms that are predicted to be small according to the model fall into one of the two groups of firms with the lowest actual output. The 'medium' category is quite evenly spread out over all levels of total output, whereas the 'large' category is predominant among the firms with large productions, with 74% of the firms in this group falling into the two top categories of actual output. A simple, univariate regression shows that more than 23% of the variation in the actual company size distribution can be explained by the predicted size categories. This gives a first indication that the theoretical model may capture some of the underlying mechanisms in the real world: that the smallest, least productive firms source domestically, whereas only the most productive firms choose FDI. To test the model more stringently, I thus turn to the more specific predictions of the model, which to the best of my knowledge, has not been predicted by theoretical contributions in this literature before.

Predictions 1-4 in section 2 stated that the intensity of each individual sourcing option would be functions of the productivity of firms. More specifically, my model predicted that outsourcing in the north would be decreasing in firms' productivity and integration in the north would be strongly concave, whereas both outsourcing and integration in the south would be increasing in the firms' productivity. I test the mentioned predictions by regressing the share of intermediate inputs that the firms acquire through each sourcing option on productivity measures estimated by the Olley-Pakes method (Olley and Pakes, 1996) and the control variables discussed above, separately. These shares are bounded from below at 0% for all sourcing options, and also from above at 100% in the case of domestic and foreign outsourcing. I therefore use the Tobit model and censored regression to adjust for this. The results are shown in Table 3. It may be that establishing partnerships for outsourcing, or building integrated plants domestically or abroad, may take some time. Further, it has also been argued that firms that are controlled by foreigners will lack some domestic knowledge, while having superior knowledge about their own country, and that this will affect their sourcing strategies. I thus follow Kohler and Smolka (2009) and restrict the sample to firms that have existed for five years or more, and also exclude foreign firms, by which I mean firms where more than 33% of the shares are controlled by foreign shareholders.[14] Since the predicted effects of productivity on sourcing behavior are likely to be non-linear for most forms of $t(\omega)$ I include the squared term of productivity to allow for some non-linearity of a second-degree kind. As before, the results are reported for 2007, since these results are closest to the average results over the three years, for which I have the relevant data, but the results for 2006 and 2008 are again practically

[14] Among these "foreign firms," 96.51% are 50% or more controlled by foreign shareholders, and 83.95% have at least 98% of their shares controlled by foreign shareholders. 77.11% are 100% foreign-owned. Not very surprisingly, the results do not change much when I use 50% or 100% foreign shareholding as cutoff-levels for defining foreign firms.

identical. Regressions (1)-(4) show the tests of the predicted relationship between PRODUCTIVITY and the respective sourcing options. The relationships do seem to be quite non-linear. All coefficients that are predicted by predictions 1-4 are of the expected sign, and most of them are statistically significant. The effect of PRODUCTIVITY on foreign vertical integration seems somewhat less statistically significant than the others, but this might come from the fact that only about 200 of the firms in the sample source any intermediate input through this channel. The economic importance of these effects does also seem to be important. From the average level of productivity, a 10% productivity increase would predict a -1.75 percentage points change in domestic outsourcing, whereas domestic vertical integration, foreign outsourcing and foreign vertical integration would be expected to increase by 4.12, 4.77, and 5.26 percentage points, respectively. The main conclusions from studying regressions (1)-(4) however, is that none of the predictions 1-4 can be rejected. The results also show that sourcing behavior varies quite a lot between firms.

Compared to the model, there are some differences in the data. One example is that as many as 40% of the firms in this sample report sourcing percentages that add up to less than 100%. This is not a big problem, as in the real world some firms would produce some intermediate inputs themselves, in contrast to only producing headquarter services as assumed in the model. In-house production should best be thought of as a form a vertical integration, and the closest equivalent to the model would thus be to proxy $NI = 100 - (NO + SO + SI)$. Doing this does not change the results significantly, and I conclude that this deviation between the model and the data is not a problem. Another issue that might be of more concern, is that the dependent variables are connected through the substitutability between them. This could mean that a seemingly unrelated regressions approach would yield more efficient coefficients; however, the bias from a linear estimation on the truncated data would be of more concern, and I thus prefer to run with the tobit analysis. The tobit-model on the other hand hinges on the rather strict assumption that the error terms are normally distributed. A test for normality after tobit estimation derived by Skeels and Vella (1999) is thus run on regressions (2) and (4), and null hypothesis of normality cannot be rejected in any of these cases.[15]

	(1) NO	(2) NI	(3) SO	(4) SI
Productivity	-17.54**	39.28**	66.50**	102.2*
	(-2.44)	(2.33)	(2.35)	(1.94)
Productivity squared	1.688**	-3.710**	-7.028**	-11.51*
	(2.26)	(-1.99)	(-2.34)	(-1.88)
Export status	-13.66***	14.16***	109.7***	38.73***
	(-5.10)	(3.03)	(9.94)	(3.25)
Similar products	-11.81**	16.17**	24.38	57.43***
	(-2.06)	(2.11)	(1.27)	(4.96)
Capital intensity	-0.0880**	0.159***	0.129	0.0197
	(-2.01)	(2.80)	(0.82)	(0.20)
R&D intensity	-0.235	2.975***	5.944**	0.411
	(-0.26)	(2.63)	(1.96)	(0.27)
Capacity utilization	0.222***	-0.279*	-0.100	0.207
	(2.60)	(-1.94)	(-0.32)	(0.68)
Pseudo R^2	0.00873	0.0652	0.0390	0.118
N	1663	1663	1653	1663

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 3: Productivity and sourcing behavior

For tractability and simplicity, none of the control variables in Table 3 were incorporated in the theoretical model. Nonetheless, the analysis shows that some of these variables have important and interesting effects on the firms' sourcing strategies. Equation (2) showed that output is a convexly increasing function of productivity. The relationship between productivity and EXPORT STATUS has been widely argued in the international trade literature (see for example Clerides et al., 1998; Bernard and Jensen, 1999; Bernard et al., 2003; and many others), and strong support has been found for a selection effect that more productive firms self-select into exporting. More mixed results are found for the learning effect of exporting, i.e. whether exporting firms increase their productivity after becoming exporters. Table 3 shows that *ceteris paribus,* exporters use domestic outsourcing

[15]The tobcm test cannot be run on regressions (1) and (3) as this test can only be used on left-censored regressions with zero as the censoring point.

options less intensively than non-exporters do, and use all other sourcing options more intensively. These results may indicate that the costs of sourcing abroad may be lower if the firm already has some sales network operating abroad. Caution has to be taken, however, as this effect may just as well be in the other direction: that foreign outsourcing makes establishing an export network cheaper, and thus makes exporting more likely for firms that are already sourcing abroad.[16] Further, it may be the sourcing from sources with lower variable costs that contribute to the export status through lowering unit costs, and thus the competitiveness of the good; however, using the lagged variable of export status does not change the results.[17]

My proxy for horizontal FDI (SIMILAR PRODUCT) yields the expected results, as it is positive and statistically significant for the use of vertical integration, especially foreign vertical integration, which I interpret as an indication that these corporate groups have established plants producing intermediate inputs, which it delivers to several final producers around the world, and as such captures a volume effect that is not captured in the theoretical model, nor by the productivity effect in the empirical analysis. The effect on domestic outsourcing is negative and statistically significant, and for foreign outsourcing it is positive, but not significantly different from zero. This could also be coherent with the hypothesis that international conglomerates centralize their sourcing, both in vertically integrated plants and the inputs they contract at arm's-length. The effects of CAPITAL INTENSITY and R&D INTENSITY on firms' sourcing behavior is a bit harder to interpret, but there seem to be some effects going on, and they should be used to control for whatever mechanisms this might be. In the theoretical model, firms will always invest for, and produce the optimal quantity of goods, and therefore

[16] A random effects probit regression shows that firms with higher use of foreign outsourcing (4.29) and foreign vertical integration (3.27) are significantly more likely to be exporters, while domestic outsourcing (-3.20) and vertical integration (-3.05) reduces this likelihood (z-values are shown in parentheses). A fixed effect logit, however, generates coefficients of the same signs, but these are not statistically significant. This is not very surprising, since I only have information for these variables for the period 2006-08, and the low variance in export status over this period reduces the sample to a mere 442 observations.

[17] Other concerns could be that there is collinearity between productivity and export status, as argued theoretically by Melitz (2003) and Helpman et al. (2004) and others. However, the correlation between the two is a mere 0.04, so collinearity should not be a problem in the econometrical analysis.

always produce at full capacity. The uncertainties of the real world are naturally not compatible with this, as shown in the coefficient for the variable CAPACITY UTILIZATION. This variable has a positive and significant effect on the use of domestic outsourcing (NO), and a negative effect on the use of domestic vertical integration (NI). My interpretation of this is that outsourcing domestically is the sourcing option with the lowest fixed cost, and is therefore a natural choice of sourcing in order to cover a temporal increase in demand. The negative effect on vertical integration could reflect its lack of flexibility, and thus the counter-cyclical intensity in the use of this sourcing option.

Table 4 shows the results for using two alternative measures of productivity: output per worker and value added per worker. These results are shown in Table 4.

Regressions (5)-(9) use output per worker as the productivity measure, whereas regressions (10)-(13) use value added per worker. The results are qualitatively very similar to the results from regressions (1)-(4), using the Olley-Pakes productivity measures as the main explanatory variable. The coefficients for the alternative productivity measures are also statistically significant in most cases. As the productivity estimates in Table 4 are not very sophisticated, while the Olley-Pakes productivity estimates are arguably the best estimates methodologically, and since they are also the most commonly used in the literature, I will use these estimates as my productivity variable in the following.

	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
		Output per worker				Value added per worker		
	NO	NI	SO	SI	NO	NI	SO	SI
Productivity	-21.89***	42.75***	134.5***	32.75**	-0.311*	1.130***	2.074***	0.676
	(-4.55)	(6.26)	(7.46)	(2.43)	(-1.69)	(3.82)	(3.15)	(1.29)
Productivity squared	4.148***	-6.459***	-20.51***	-4.701*	0.00122	-0.00640***	-0.00695**	-0.00414
	(3.95)	(-4.80)	(-5.44)	(-1.77)	(1.31)	(-3.19)	(-2.21)	(-1.31)
Export status	-11.69***	10.27**	98.51***	36.98***	-14.28***	13.06***	109.8***	39.40***
	(-4.32)	(2.20)	(9.13)	(3.12)	(-5.31)	(2.78)	(9.89)	(3.31)
Similar products	-11.23*	16.11**	18.54	57.52***	-11.70**	15.65**	21.94	56.93***
	(-1.96)	(2.13)	(0.99)	(4.99)	(-2.03)	(2.03)	(1.13)	(4.91)
Capital intensity	-0.0464	0.0459	-0.344**	-0.0929	-0.0631	0.0808	-0.0803	-0.0258
	(-0.97)	(0.76)	(-1.99)	(-0.85)	(-1.30)	(1.26)	(-0.46)	(-0.23)
R&D intensity	-0.182	2.288**	3.818	-0.157	-0.224	3.599***	4.597	1.423
	(-0.20)	(2.03)	(1.28)	(-0.10)	(-0.23)	(2.83)	(1.45)	(0.69)
Capacity utilization	0.219***	-0.298**	-0.285	0.197	0.209**	-0.281*	-0.216	0.208
	(2.59)	(-2.10)	(-0.92)	(0.65)	(2.44)	(-1.95)	(-0.68)	(0.68)
Pseudo R^2	0.00982	0.0746	0.0483	0.120	0.00843	0.0664	0.0403	0.115
N	1676	1676	1676	1676	1668	1668	1668	1668

t statistics in parentheses
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

Table 4: Alternative productivity measures

The above testing of Predictions 1-4 indicates that the model may very well describe an important mechanism for firms' use of different sourcing options. In the motivation for this paper, however, I argued for the relevance of sourcing strategies, i.e. the combination of all the sourcing options the firm decides to use. The theoretical model generates clear predictions on which such strategies are compatible with the model, and also in which order they can be ranked by firm productivity. In the model, there can, depending on the form of $t(\omega)$, be 10 different sourcing strategies, ranked by productivity of the firms that will use them, with the most productive firms choosing SI and the least productive choosing NO:[18]

Sourcing strategy	Rank	Percentage of firms
SI	1	0.2%
$SO + SI$	2	0.2%
$NO + SO + SI$	3	4.9%
SO	4	1.6%
$NI + SO$	5	0.1%
$NO + SO$	5	26.9%
$NO + NI + SO$	7	5.8%
NI	8	0.8%
$NO + NI$	9	4.7%
NO	10	45.3%

A first examination of these possible strategies reveal that they cover only 10 of the 15 strategies that could possibly exist in the real world. However, these 10 strategies account for 90.7% of the strategies that the firms in the sample actually choose. Firms with more than 200 employees are overrepresented in the sample, and splitting the sample in large and small firms along this demarcation criteria, I find that the 10 sourcing strategies permitted by the model account for 84.0% of the strategies used by large firms, and 93.3% of the strategies chosen by the small firms. The most important strategy that is excluded by the theoretical model,

[18]Not all these strategies can potentially occur for a specific function form of $t(\omega)$, but all strategies are possible under one form or another of $t(\omega)$. The ranking along firm productivity is unambiguous, with the exception of the ranking of NISO and NOSO, as they will never both occur for a specific function form of $t(\omega)$. These two strategies are thus ranked as equal on the productivity scale.

is NONISOSI, sourcing from all the possible sourcing options. This strategy is used by 3.1% of the firms in the data. In the subsamples, this value is 9.1% for the large firms, and 0.8% among the small firms. I thus argue that the sourcing options that are not rationally used, according to the theoretical model, are not commonly used among firms in my data sample either, with the exception of some of the largest firms that use all four sourcing options. Further, the model also predicts a ranking of these most-used sourcing strategies along the productivity axis. Based on this theoretical ranking, an ordered logit regression on sourcing strategy coded inversely to the one shown above should show a positive coefficient for the productivity measures. The result of such a regression is shown in Table 5.

	(14) Ordered logit Sourcing strategies	(15) Tobit Offshoring	(16) Tobit Vertical integration
Productivity	1.077***	73.64**	49.85***
	(2.64)	(2.47)	(2.64)
Productivity squared	-0.115**	-7.709**	-4.905**
	(-2.53)	(-2.44)	(-2.32)
Export status	1.407***	115.28***	18.53***
	(11.82)	(9.88)	(3.73)
Similar product	0.476*	43.06**	34.53***
	(1.93)	(2.10)	(4.46)
Capital intensity	0.0010	0.111	0.151**
	(0.55)	(0.67)	(2.49)
R&D intensity	0.089*	8.892**	2.583**
	(1.83)	(2.45)	(2.15)
Capacity utilization	-0.0015	-0.108	-0.248
	(-0.41)	(-0.32)	(-1.63)
Pseudo R^2	0.0828	0.0416	0.0640
N	1555	1663	1663

t statistics in parentheses
$* p < 0.10$, $** p < 0.05$, $*** p < 0.01$

Table 5: Sourcing strategies

Indeed, the coefficients for productivity in regression (14) show the expected sign, as predicted by the theoretical model. This indicates that firms sort into the different sourcing strategies based on their productivity.

One question in the debates around the "disintegration of production" has been the degree of offshoring, the moving of jobs out of the country. There are many reasons this topic raises debates, as it is easy to understand that such movement of tasks to foreign countries will affect local labor markets, although as mentioned above, the literature is ambiguous about how it will affect wage levels. In regression (15) I group together the share of intermediate inputs that the firms buy from both related and unrelated firms outside of Spain. Not surprisingly, and in accordance with previous studies, these regressions show that larger, more productive firms offshore more tasks and import more intermediate inputs from abroad than less productive, smaller firms. Again, the effect seems to be concave. In the next regression, (16), I run a similar regression, but on the sum of the shares of intermediate inputs bought from vertically integrated plants both in Spain and abroad. Also this relationship seems to be positive, but concave; larger, more productive firms use more inputs from vertically integrated plants. Also the signs of the control variables seem to be consistent with the above interpretations from the regressions on individual sourcing options.

4 Conclusion

In this paper I have developed a theoretical model for firms' sourcing decisions that incorporates dimensions from the productivity-driven sorting mechanism from Antràs and Helpman (2004), as well as the task-trading from Grossman and Rossi-Hansberg (2008). Combining this with some fixed costs associated with each task I get a framework where firms sort into sourcing strategies, as in the simultaneous use of several sourcing options, both domestically and abroad. To the best of my knowledge, this is the first sourcing model to generate such rich testable predictions on the "disintegration of industrial production." The model also predicts the intensity in the use of each individual sourcing option as functions of output levels and productivity, as well as the degree of both offshoring and the existence of multi-plant firms.

Testing these predictions on firm-level data from Spanish firms, a first observation is that around half of the firms in the sample use more than one sourcing option, indicating the empirical relevance of models that allow for sourcing strategies that use a combination of sourcing options. In the more detailed testing of the use of sourcing options, and sourcing strategies, I find quite strong support for the model's predictions. A couple of caveats concerning the data should however be pointed out. One is that large firms are overrepresented in the sample, and since firm size is an important factor in predicting sourcing behavior, this might affect the magnitude of the results. Although I have controlled for this as much as possible, and find that the main results hold also for the sub-sample of only firms with less than 200 employees, it would be preferable to estimate the effects on a more representative sample. Secondly, data on sourcing behavior have only been recorded since 2006, and since these are long-term decisions for firms, there is very little variance over time to permit the use of econometric panel data techniques, and causality is thus difficult to establish. This implies that the relation between higher estimated productivity and the use of foreign sourcing and vertical integration, may run both ways, and even be a self-reinforcing effect. Literature on productivity premiums among exporters discusses selection into and learning from exporting, effects that would be highly relevant to estimate for sourcing strategies as well, although at this point in time the data does not permit this line of investigation.

Finally, the empirical testing shows that there is a strong relation between exporting and sourcing strategies. This is not surprising, as in my model the mechanisms that drive the use of sourcing options with higher fixed costs, but lower variable costs, are exactly the same mechanisms that cause firms to export in models like that of Melitz (2003). This means that the empirical relation could possibly just be a spurious one, although I find that hard to believe. There are likely to be synergies between international production and international distribution, and also between lowering marginal costs of production and becoming more competitive in the international market. Integrating my model into a Helpman et al. (2004) type of sorting mechanism for exporting and FDI would thus be an interesting next step in this research.

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Appendix A1: Proof that variable costs are decreasing in production intensity

The optimal constant marginal costs of production are

$$\begin{array}{rc} c^{s}(s)= & \int_{0}^{\omega_{NONI}} t(\omega)\, w^{N} d\omega+\int_{\omega_{NONI}}^{1} w^{N} d\omega \\ c^{m}(s)= & \int_{0}^{\omega_{NOSO}} t(\omega)\, w^{N} d\omega+\int_{\omega_{NOSO}}^{\omega_{SONI}} t(\omega)\, w^{S} d\omega+\int_{\omega_{SONI}}^{1} w^{N} d\omega \\ c^{l}(s)= & \int_{0}^{\omega_{NOSO}} t(\omega)\, w^{N} d\omega+\int_{\omega_{NOSO}}^{\omega_{SOSI}} t(\omega)\, w^{S} d\omega+\int_{\omega_{SOSI}}^{1} w^{S} d\omega \end{array}.$$

It is possible to show how these change wrt x by looking at the indirect effect of this through the cutoff ω's. The above expressions are for situations where $0<\omega_{NONI},\omega_{NOSO},\omega_{SONI},\omega_{SOSI}<1$. If this is not the case, the expressions will reach corner solutions. Consider for example the possible situation for medium-sized firms if $\omega_{NOSO}<0<1<\omega_{SONI}$. In this case these firms will source all intermediate inputs through foreign outsourcing, and their variable costs of production will thus be $\int_{0}^{1} t(\omega)\, w^{S} d\omega$, which is independent of x. Such corner solutions can, however, never lead to a positive relationship between x and $c(s)$, so by showing that $\frac{\partial c(s)}{\partial x}$ for all the interior solutions described above I will have proved that $c(s)$ is non-increasing in x for all possible values of x, including corner solutions.

For small firms the change in costs from a change in x will be

$$\begin{aligned} \frac{\partial c^{s}(s)}{\partial x} &= \frac{\partial c^{s}(s)}{\partial \omega_{NONI}} \frac{\partial \omega_{NONI}}{\partial x}=\frac{\partial \omega_{NONI}}{\partial x} \frac{\partial}{\partial \omega_{NONI}}\left[\int_{0}^{\omega_{NONI}} t(\omega)\, w^{N} d\omega+\int_{\omega_{NONI}}^{1} w^{N} d\omega\right] \\ &= \frac{\partial \omega_{NONI}}{\partial x} \frac{\partial}{\partial \omega_{NONI}}\left[T(\omega_{NONI})-T(0)+1-\omega_{NONI}\right] w^{N} \\ &= \frac{\partial \omega_{NONI}}{\partial x}\left[t(\omega_{NONI})-1\right] w^{N}, \end{aligned}$$

where $T(\omega)=\int t(\omega)$. Inserting for $t(\omega_{NONI})$ we get

$$\frac{\partial c^{s}(s)}{\partial x}=\underbrace{\frac{\partial \omega_{NONI}}{\partial x}}_{0>} \underbrace{\frac{f_{I}^{N}-f_{O}^{N}}{x}}_{>0}<0.$$

Since $t(\omega)$ is monotonically increasing in ω, the same must be true for the inverse function. This implies that since

$$\frac{\partial t\left(\omega_{NONI}\right)}{\partial x}=-\frac{f_I^N-f_O^N}{w^N x^2}<0 \Longrightarrow \frac{\partial \omega_{NONI}}{\partial x}<0.$$

With $\frac{f_I^N-f_O^N}{x}>0$ and $\frac{\partial \omega_{NONI}}{\partial x}<0$ it must be the case that $\frac{\partial c^s(s)}{\partial x}<0$, and I have shown that costs are monotonically decreasing in x for small firms. Following the above approach, it is also easy to show that the same must be the case for medium and large firms. For medium-sized firms

$$\begin{aligned}
\frac{\partial c^m(s)}{\partial x} &= \frac{\partial c^m(s)}{\partial \omega_{NOSO}}\frac{\partial \omega_{NOSO}}{\partial x}+\frac{\partial c^m(s)}{\partial \omega_{SONI}}\frac{\partial \omega_{SONI}}{\partial x}\\
&= \frac{\partial \omega_{NOSO}}{\partial x}\frac{\partial}{\partial \omega_{NOSO}}\left[\int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega+\int_{\omega_{NOSO}}^{\omega_{SONI}} t(\omega)\, w^S d\omega+\int_{\omega_{SONI}}^{1} w^N d\omega\right]\\
&\quad +\frac{\partial \omega_{SONI}}{\partial x}\frac{\partial}{\partial \omega_{SONI}}\left[\int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega+\int_{\omega_{NOSO}}^{\omega_{SONI}} t(\omega)\, w^S d\omega+\int_{\omega_{SONI}}^{1} w^N d\omega\right]\\
&= \underbrace{\frac{\partial \omega_{NOSO}}{\partial x}}_{0>}\underbrace{\frac{f_O^S-f_O^N}{x}}_{>0}-\underbrace{\frac{\partial \omega_{SONI}}{\partial x}}_{>0}\underbrace{\frac{f_O^S-f_I^N}{x}}_{>0}<0,
\end{aligned}$$

since

$$\begin{aligned}
\frac{\partial t\left(\omega_{NOSO}\right)}{\partial x} &= -\frac{f_O^S-f_O^N}{\left(w^N-w^S\right)x^2}<0\\
\frac{\partial t\left(\omega_{SONI}\right)}{\partial x} &= \frac{f_O^S-f_I^N}{w^S x^2}>0.
\end{aligned}$$

For large firms the change in costs from a change in x will be:

$$\begin{aligned}\frac{\partial c^l(s)}{\partial x} &= \frac{\partial c^l(s)}{\partial \omega_{NOSO}}\frac{\partial \omega_{NOSO}}{\partial x}+\frac{\partial c^l(s)}{\partial \omega_{SOSI}}\frac{\partial \omega_{SOSI}}{\partial x}\\ &= \frac{\partial \omega_{NOSO}}{\partial x}\frac{\partial}{\partial \omega_{NOSO}}\left[\int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega+\int_{\omega_{NOSO}}^{\omega_{SOSI}} t(\omega)\, w^S d\omega+\int_{\omega_{SOSI}}^{1} w^S d\omega\right]\\ &\quad +\frac{\partial \omega_{SOSI}}{\partial x}\frac{\partial}{\partial \omega_{NOSO}}\left[\int_0^{\omega_{NOSO}} t(\omega)\, w^N d\omega+\int_{\omega_{NOSO}}^{\omega_{SOSI}} t(\omega)\, w^S d\omega+\int_{\omega_{SOSI}}^{1} w^S d\omega\right]\\ &= \underbrace{\frac{\partial \omega_{NOSO}}{\partial x}}_{0>}\underbrace{\frac{f_O^S-f_O^N}{x}}_{>0}+\underbrace{\frac{\partial \omega_{SOSI}}{\partial x}}_{0>}\underbrace{\frac{f_I^S-f_O^S}{x}}_{>0}<0,\end{aligned}$$

since

$$\begin{aligned}\frac{\partial t(\omega_{NOSO})}{\partial x} &= -\frac{f_O^S-f_O^N}{(w^N-w^S)\,x^2}<0\\ \frac{\partial t(\omega_{SOSI})}{\partial x} &= -\frac{f_I^S-f_O^S}{w^S x^2}<0.\end{aligned}$$

I have thus shown that $\frac{\partial c(s)}{\partial x} \leq 0 \forall x$.

Appendix A2: Production intensity and productivity

The firms' profit function is given by

$$\pi = A^{1-\rho}(\theta x)^{\rho}-c(x)\,x-f(x),$$

with corresponding first order conditions:

$$\rho A^{1-\rho}\theta^{\rho}x^{\rho-1}-\frac{\partial c(x)}{\partial x}x-c(x)-\frac{\partial f(x)}{\partial x}=0.$$

Total differentiation of this FOC yields:

$$\frac{dx}{d\theta}=\frac{\rho^2 A^{1-\rho}\theta^{\rho-1}x^{\rho-1}}{\rho\left(1-\rho\right)A^{1-\rho}\theta^{\rho}x^{\rho-2}+\frac{\partial^2 c(x)}{\partial x^2}x+2\frac{\partial c(x)}{\partial x}+\frac{\partial^2 f(x)}{\partial x^2}}.$$

The numerator in this expression is always positive, whereas the denominator contains both positive and some potentially negative elements. For the FOC to denote a maximum, however, it must be that the second-order condition holds; $\frac{\partial^2\pi}{\partial x^2}<0$:

$$\rho\left(1-\rho\right)A^{1-\rho}\theta^{\rho}x^{\rho-2}+\frac{\partial^2 c\left(x\right)}{\partial x^2}x+2\frac{\partial c\left(x\right)}{\partial x}+\frac{\partial^2 f\left(x\right)}{\partial x^2}>0,$$

which is simply the denominator in the expression above. This implies that in optimum, an increase in productivity will increase the optimal production intensity, and $\frac{dx}{d\theta}>0$. There will be a unique optimum if the SOC holds for all values of x. Intuitively, this will be the case if the reduction in marginal costs from an increase in x is never larger than the reduction in marginal revenue from the same change in x. In such a situation, a marginal increase in x would lead to a drop in variable costs of production sufficiently large to cause an even larger increase in x, and thus lead to a self-reinforcing process of falling costs and increasing production. If there are never such self-reinforcing effects, $\frac{\partial^2\pi}{\partial x^2}<0\forall x$, and the equilibrium is unique.

Appendix A3: Mapping of the sourcing strategies

With four different sourcing options (NO, NI, SO, SI) there should exist six different $t\left(\omega\right)$-loci. However, the variable costs of both NI and SI are indifferent to $t\left(\omega\right)$, which means that for a given production intensity, one of these will be preferred to the other for all ω. More specifically, for $x<x_{NISI}=\frac{F_I^S-F_I^N}{w^N-w^S}\implies NI\succ SI$ and vice versa. This leaves me with five $t\left(\omega\right)$-loci, which should imply a total of ten cutoff-values for x. Again there is a special case, as it turns out that $\omega_{SOSI}>\omega_{NONI}\ \forall\ x$. There are thus nine x-cutoffs that determine the rankings of $t\left(\omega\right)$-loci, plus x_{NISI} that determine when $NI\succ SI$. The complete list of these

x-values in descending order is:

$$\begin{aligned}
x_{NOSINONI} &= x_{SOSISONI} = x_{NISI} = \frac{f_I^S - f_I^N}{w^N - w^S} \\
x_{SONINOSI} &= \frac{w^N\left(f_O^S - f_I^N\right) + w^S\left(f_I^S - f_O^N\right)}{\left(w^N - w^S\right)\left(w^N + w^S\right)} \\
x_{SONINONI} &= x_{NOSOSONI} = x_{NOSONONI} = \frac{w^N\left(f_O^S - f_I^N\right) + w^S\left(f_I^N - f_O^N\right)}{w^N\left(w^N - w^S\right)} \\
x_{NOSONOSI} &= x_{NOSISOSI} = x_{NOSOSOSI} = \frac{w^S\left(f_I^S - f_O^N\right) - w^N\left(f_I^S - f_O^S\right)}{w^S\left(w^N - w^S\right)}.
\end{aligned}$$

Category	x
1	$x_{NOSONOSI} > x$
2	$x_{NOSOSONI} > x > x_{NOSONOSI}$
3	$x_{SONINOSI} > x > x_{NOSOSONI}$
4	$x_{NOSINONI} > x > x_{SONINOSI}$
5	$x > x_{NOSINONI}$

This implies that for the smallest firms with $x < x_{NOSONOSI}$ it will be the case that

$\omega_{NOSO} > \omega_{NOSI}$	$\omega_{NOSI} > \omega_{SONI}$	$\omega_{SOSI} > \omega_{SONI}$	$\omega_{NONI} > \omega_{SONI}$
$\omega_{NOSO} > \omega_{SOSI}$	$\omega_{NOSI} > \omega_{NONI}$	$\omega_{SOSI} > \omega_{NONI}$	
$\omega_{NOSO} > \omega_{SONI}$	$\omega_{NOSI} > \omega_{SOSI}$		
$\omega_{NOSO} > \omega_{NONI}$			

This unambiguously determines the complete order to be

$$\omega_{NOSO} > \omega_{NOSI} > \omega_{SOSI} > \omega_{NONI} > \omega_{SONI}.$$

For a given production intensity x, this ranking defines six regions along the ω-axis. Below I have shown these regions for ascending ω values. Each column shows all pairwise rankings of sourcing options for that given range of ω values.[19] In each column there is one sourcing option that dominates all other sourcing options, and will be the one the firm will use for that range of tasks. The chosen sourcing option

[19] $NI \succ SI \; \forall \; \omega$ since $x < x_{NISI}$

is shown in the last row of the table.

$\omega < \omega_{SONI}$	$\omega_{SONI} < \omega < \omega_{NONI}$	$\omega_{NONI} < \omega < \omega_{SOSI}$	$\omega_{SOSI} < \omega < \omega_{NOSI}$	$\omega_{NOSI} < \omega < \omega_{NOSO}$	$\omega_{NOSO} < \omega$
$SO \succ NI$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$
$NO \succ NI$	$NO \succ NI$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$
$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SI \succ SO$	$SI \succ SO$	$SI \succ SO$
$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$SI \succ NO$	$SI \succ NO$
$NO \succ SO$	$NO \succ SO$	$NO \succ SO$	$NO \succ SO$	$NO \succ SO$	$SO \succ NO$
$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$
NO	NO	NI	NI	NI	NI

For these smallest firms, we can thus see that domestic outsourcing and domestic vertical integration will be the only sourcing options ever used. Further, the table shows that the cutoff between the two sourcing options is, quite naturally, ω_{NONI}. Similar tables for the other four production intensity categories are shown below.

Sourcing when $x_{NOSONOSI} < x < x_{NONISONI}$:

$\omega < \omega_{SONI}$	$\omega_{SONI} < \omega < \omega_{NONI}$	$\omega_{NONI} < \omega < \omega_{NOSO}$	$\omega_{NOSO} < \omega < \omega_{NOSI}$	$\omega_{NOSI} < \omega < \omega_{SOSI}$	$\omega_{SOSI} < \omega$
$SO \succ NI$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$
$NO \succ NI$	$NO \succ NI$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$
$NO \succ SO$	$NO \succ SO$	$NO \succ SO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$
$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$SI \succ NO$	$SI \succ NO$
$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SI \succ SO$
$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$
NO	NO	NI	NI	NI	NI

Sourcing when $x_{NONISONI} < x < x_{NOSISONI}$:

$\omega < \omega_{NOSO}$	$\omega_{NOSO} < \omega < \omega_{NONI}$	$\omega_{NONI} < \omega < \omega_{SONI}$	$\omega_{SONI} < \omega < \omega_{NOSI}$	$\omega_{NOSI} < \omega < \omega_{SOSI}$	$\omega_{SOSI} < \omega$
$NO \succ SO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$
$NO \succ NI$	$NO \succ NI$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$
$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$NI \succ SO$	$NI \succ SO$	$NI \succ SO$
$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$SI \succ NO$	$SI \succ NO$
$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SI \succ SO$
$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$
NO	SO	SO	NI	NI	NI

Sourcing when $x_{NOSISONI} < x < x_{NOSINONI}$:

$\omega < \omega_{NOSO}$	$\omega_{NOSO} < \omega < \omega_{NONI}$	$\omega_{NONI} < \omega < \omega_{NOSI}$	$\omega_{NOSI} < \omega < \omega_{SONI}$	$\omega_{SONI} < \omega < \omega_{SOSI}$	$\omega_{SOSI} < \omega$
$NO \succ SO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$
$NO \succ NI$	$NO \succ NI$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$
$NO \succ SI$	$NO \succ SI$	$NO \succ SI$	$SI \succ NO$	$SI \succ NO$	$SI \succ NO$
$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$NI \succ SO$	$NI \succ SO$
$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SI \succ SO$
$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$	$NI \succ SI$
NO	SO	SO	SO	NI	NI

Sourcing when $x_{NOSINONI} < x$:

$\omega < \omega_{NOSO}$	$\omega_{NOSO} < \omega < \omega_{NOSI}$	$\omega_{NOSI} < \omega < \omega_{NONI}$	$\omega_{NONI} < \omega < \omega_{SOSI}$	$\omega_{SOSI} < \omega < \omega_{SONI}$	$\omega_{SONI} < \omega$
$NO \succ SO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$	$SO \succ NO$
$NO \succ SI$	$NO \succ SI$	$SI \succ NO$	$SI \succ NO$	$SI \succ NO$	$SI \succ NO$
$NO \succ NI$	$NO \succ NI$	$NO \succ NI$	$NI \succ NO$	$NI \succ NO$	$NI \succ NO$
$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SO \succ SI$	$SI \succ SO$	$SI \succ SO$
$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$SO \succ NI$	$NI \succ SO$
$SI \succ NI$	$SI \succ NI$	$SI \succ NI$	$SI \succ NI$	$SI \succ NI$	$SI \succ NI$
NO	SO	SO	SO	SI	SI

Together, these five tables and the cutoff production intensities show all the information needed to draw Figure 1 in the paper.

Department of Economics
University of Bergen
Fosswinckels gate 14
N-5007 Bergen, Norway
Phone: +47 55 58 92 00
Telefax: +47 55 58 92 10
http://www.svf.uib.no/econ