

Outsourcing, Productivity, and Input Composition at the Plant Level

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Abstract

Outsourcing or subcontracting is increasingly used by firms as a production alternative, which would be expected to affect productive performance as well as input mix. To evaluate outsourcing relationships for plants in a less developed country, we first estimate within-industry proportional differences in various performance indicators between plants that subcontract inputs or outputs and plants that do not engage in outsourcing activity for Turkish textile and apparel manufacturing plants. We find that plants that outsource internationally exhibit better performance than plants that choose to outsource in the domestic market, especially for plants that subcontract outputs. We then evaluate labor productivity gaps before and after outsourcing, and find that more productive plants tend to engage in input and international outsourcing but also increase their relative productivity after beginning outsourcing. We further explore the relationships among outsourcing and productivity, input composition, and trade by estimating a flexible transformation function model by methods that control for simultaneity and selection bias. We find that the higher productivity of plants that engage in input subcontracting and foreign outsourcing involves greater skilled labor intensity, and that the reverse is true for output subcontracting plants.

Keywords: outsourcing, plant productivity, input composition, trade and labor biases

JEL Classifications: D24, F14, L60

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“... quite apart from the question of diminishing returns the costs of organizing certain transactions within the firm may be greater than the costs of carrying out the exchange transactions in the open market.” Coase (1937), pp. 7-8.

Introduction

The productivity of firms depends on their potential to minimize production costs by substituting among a variety of inputs. Input choices include purchasing rather than producing goods and services, which implies outsourcing or subcontracting. Although there is increasing diversification among firms' input choices, and wide recognition in policy circles and by the public of the consequences of outsourcing, most production studies consider a limited input specification that ignores such changes in input form.

Many empirical production studies focus on “value added” capital and labor inputs without recognizing the potential to substitute processed materials inputs for processing (capital and labor) inputs. Even when such substitution is recognized, substitution within input categories – such as skilled versus unskilled labor or domestic versus foreign materials – is typically not allowed for. Although producers' substitution responses increasingly involve both foreign and domestic outsourcing, the limited input representations common in the production literature preclude consideration of such trends and thus limit the interpretability of resulting estimates.

Firms would be expected to allocate their own inputs to activities for which they have a comparative advantage over competitors and outsource the remaining activities to external suppliers (Roodhooft and Warlop, 1999), and the relative advantages of these choices will be affected by technological, market, and trade conditions. For example, especially for developed countries, import competition from low wage countries may result

in foreign outsourcing, and thus reduce the demand for and wages of less skilled laborers (Feenstra and Hanson, 1996, 1999, 2003, Hanson et al. 2005). In reverse, especially for developing countries, firms may subcontract output to higher-wage firms that outsource or subcontract specialized tasks, *or* subcontract lower productivity/skill processes to other domestic firms. Such firms may also attempt to outsource internationally by importing materials from other countries (Görg, Hanley and Strobl, 2007, Yasar and Paul, 2007b) – in effect outsourcing their intermediate materials production to more technologically advanced firms.

Such behavior would be expected to be related to the productivity and competitiveness of firms, sectors and countries. It thus also will be related to social welfare, with policy consequences. For example, reduced employment from outsourcing likely implies higher measured labor productivity, which if interpreted as welfare enhancing may be misleading. If such a change involves shifting jobs to foreign countries, through foreign outsourcing, it may weaken the domestic labor market. Domestic employment shifts toward lower paying service activities may also result from domestic outsourcing or subcontracting.

Antras and Helpman (2004) show theoretically that if the fixed cost of outsourcing internationally is larger than outsourcing domestically, only the most productive firms will choose to outsource internationally.¹ Görg, Hanley and Strobl (2007) find empirically that international outsourcing of services has a positive productive impact on the productivity of exporting but not domestic firms. However, Helpman (2006) notes that it has been difficult to empirically establish the patterns of firms sorting into outsourcing choices

¹ For an excellent review of this literature see Helpman (2006).

(outsourcing at home, integration at home, outsourcing abroad and integration abroad) because of data limitations.

Our data for Turkish manufacturing plants in the apparel and textiles industries, however, provide a rich basis for examining the productive patterns associated with different types of outsourcing behavior. In particular, our data allow us not only to distinguish technical/administrative and production labor, energy and intermediate materials, but also to measure the shares of subcontracted inputs, subcontracted outputs, imported materials, exported output, and foreign ownership. We use these detailed data to explore the productive relationships and interactions of outsourcing and other productive factors from various perspectives.

We initially estimate within-industry proportional differences in performance indicators, or premia, controlling for plant characteristics such as location and size, between plants in each outsourcing category and plants that do not engage in outsourcing activity. We consider the impacts of both domestic outsourcing, through the share of inputs that are subcontracted, and foreign outsourcing, through the share of intermediate inputs that are imported. We also consider the performance implications of “receiving” contracts (Taymaz and Kilicaslan, 2005), through the share of output that is subcontracted. The resulting premia estimates identify relationships between performance patterns and outsourcing without addressing (or requiring knowledge of) the underlying causation.

We then consider why firms that engage in outsourcing might have better (or worse) performance characteristics. In particular, higher productivity plants may self select into outsourcing, or outsourcing/subcontracting may lead to higher performance, or both. We test these hypotheses by dividing the plants into non-starters (no outsourcing in

year t-1 or year t) and starters (no outsourcing in year t-1 but outsourcing in year t). We then evaluate the labor productivity differences between the two groups in year t-1 to determine if self selection is important; if so, starters will be more productive than non-starters. We also compare the labor productivity *growth* rates between the two groups to see if the initial productivity differential narrows, widens, or remains the same after the starters enter the market; if outsourcing increases productivity this gap should widen.

We then explore in more detail how outsourcing or subcontracting is related to plant productivity and input composition by evaluating substitution between own and outsourced inputs, controlling for the effects of other productive factors. This requires empirical representation of the production technology, which we accomplish by estimating a flexible transformation function model. Such a function represents the production technology – the most output(s) producible from given inputs, firm characteristics, and external factors – rather than inferring behavior or causation. However, econometric estimation still faces potential endogeneity issues, such as the self selection suggested from our labor productivity analysis. For estimation we therefore use lagged values of the potentially endogenous variables as well as a semi-parametric estimation method that accommodates self selection and simultaneity issues.

The productivity implications of outsourcing are represented as higher or lower production frontiers associated with varying shares of input, output, or international outsourcing, similar to Görg, Hanley and Strobl's (2007) treatment of materials imports. However, unlike Görg, Hanley and Strobl's Cobb-Douglas approximation of the technology, our translog functional form allows us to capture input composition (second-order) effects reflecting differences in inputs' relative output elasticities, or the production

frontier slope, for outsourcing plants. Similarly, estimated interactions among outsourcing and trade variables such as exporting and foreign ownership show whether outsourcing effects differ for plants with other foreign linkages.

Our premia results show that plants that outsource domestically (subcontract inputs) and that outsource internationally (import inputs) are larger, more productive, and have higher skilled labor and capital than the control (non-outsourcing) plants. The reverse is true for firms that outsource outputs. Our labor productivity estimates show that higher productivity plants self-select into outsourcing, consistent with the predictions of Antras and Helpman (2004), but we also find evidence of enhanced productivity from input outsourcing both domestically and internationally.

Our production technology estimates confirm that greater shares of subcontracted inputs or imported materials imply higher plant productivity, but subcontracting outputs implies lower productivity. Further, input subcontracting is significantly skilled-labor-using, although importing materials does not substantively affect input composition. Output subcontracting is, in reverse, associated with both lower productivity and lower shares of skilled labor and intermediate materials, although output subcontracting plants with international linkages exhibit higher productivity than those without such linkages.

The Literature

Although outsourcing or subcontracting has not been a focus of the production and productivity literature, some studies have examined firms' decisions about whether to produce in-house or outsource (Williamson, 1971, Grossman and Hart, 1986, Abraham and Taylor, 1996, Holmes, 1986, Grossman and Helpman, 2002, Antras, 2003). This literature

stresses that cost minimization may involve outsourcing if the cost of producing inputs or services in-house are higher than (or at least as high as) subcontracting them.

Two types of costs affect firms' choices between internal production and outsourcing: production costs and transaction costs. Production costs may be minimized through subcontracting if outside suppliers benefit from lower labor costs, scale economies, clustering of special skills or expertise, or production smoothing (Abraham and Taylor, 1996 and Roodhooft and Warlop, 1999). For example, firms with higher wages may lower their costs by subcontracting some production activities to lower wage producers, which may also imply that firms that subcontract outputs are lower productivity ("technologically backward") smaller firms (Berger and Piore, 1980, Imrie, 1986). Further, smoothing the workload of a firm's regular workforce by subcontracting during demand peaks might reduce risk or product market uncertainty, or lags in responding due to capacity constraints, from seasonal variations (Holmes, 1986).

Transactions costs also affect firms' decisions about whether to produce in-house or subcontract (Coase, 1937, Williamson, 1971, Holmes, 1986, Bolton and Whinston, 1993, Abraham and Taylor, 1996, Roodhooft and Warlop, 1999).² Transaction costs may be associated with negotiating, monitoring, and enforcing contracts (Grossman and Hart, 1986) or searching for appropriate outside suppliers (Grossman and Helpman, 2002). Firms thus benefit from outsourcing only when the costs of investments required to support the subcontracting relationship are low relative to the cost advantages of subcontracting

² Grossman and Helpman (2002) note that earlier theoretical models provide limited explanations for cross sectional (or cross-regional) differences in outsourcing of firms and of recent trends, because they treat industry environment as given and ignore interdependencies among the options among firms. Further, Antras (2003) and Grossman and Helpman (2002) suggest a framework based on incomplete contract theory and search costs to examine the international outsourcing.

(Chalos, 1995, Roodhooft and Warlop, 1999).³ This may in turn suggest that larger more productive firms are the most likely to pursue input subcontracting relationships.

Productive benefits may also arise from technology transfer (Feenstra 1998, Head and Ries 2002). That is, importing materials from countries with higher levels of accumulated technical knowledge may transfer this technology through R&D embodied in the inputs and learning associated with their use. Linkages between multinational and domestic firms may also cause productivity spillovers by providing inputs at lower cost to domestic buyers (input subcontracting), or increasing demand for inputs produced by domestic suppliers (output subcontracting; Feenstra and Hanson, 2003, Grossman and Helpman, 2003, Hanson et al. 2005). This suggests that internationally connected firms may benefit differentially from outsourcing.

Some studies have empirically examined the impacts of firms' outsourcing on their economic performance.⁴ For example, Abraham and Taylor (1996) find evidence of wage cost savings, scale economies, and smoother production schedules from the use of contracting by U.S. establishments. Fixler and Siegel (1999) attribute the strong growth of U.S. service relative to manufacturing industries, and concurrent reductions in service sector productivity, at least in part to outsourcing. Ten Raa and Wolff (2001) similarly find a positive impact on total factor productivity growth from outsourcing "sluggish services" in U.S. manufacturing industries. Such studies suggest that firms in a developed country outsource less productive lower skill processes to other domestic producers.

³ Roodhooft and Warlop (1999) and Lyons (1995) empirically examine the effect of transaction costs on firms' outsourcing decisions.

⁴ Most of these studies examine the relationship between productivity and outsourcing, especially in service industries (see Heshmati, 2003, for a survey).

Further, Girma and Görg (2004) find for the U.K. that outsourcing intensity in chemical and engineering (but not electronic) manufacturing is positively associated with productivity growth, and that this effect is stronger for foreign-owned establishments. Görg, Hanley and Strobl (2007) show that outsourcing confers productivity gains for exporting and foreign-owned Irish manufacturing plants. Feenstra and Hanson (1996, 1999) conclude that foreign outsourcing in the U.S. has increasingly involved transfers of low-skill-intensive production to low-skill abundant countries. These studies suggest links to both trade factors and input composition of productivity associated with outsourcing that may differentially affect firms in a developing country.

The Data

We use an unbalanced panel dataset for Turkish apparel and textile manufacturing plants in 1990-1996 for our analysis of outsourcing and its relationships with productivity and input composition in this lower income country. The data are from Annual Surveys of Manufacturing Industries by the State Institute of Statistics in Turkey, categorized by International Standard Industrial Classification (*ISIC*). The textile (*ISIC* 32) industry has the highest subcontracted output and input shares of all industries in Turkey (Taymaz and Kilicaslan, 2005). The apparel and textile industries we use for our estimation, “textile products excluding wearing apparel” (*ISIC* 3212) and “wearing apparel, excluding fur and leather” (*ISIC* 3222) are the primary sub-sectors of this industry. After removing observations with clearly erroneous values, or that did not distinguish between technical and non-technical labor, 5235 observations for 1193 plants remained in the sample.

Our domestic outsourcing variables, subcontracted input (the share of a plant’s inputs subcontracted to supplier plants, in total inputs, *SUB_I*), and subcontracted output

(the share of output subcontracted by other plants, in total output, SUB_O), are based on the survey definition of “income from subcontract” as “income generated from the processing of materials provided by the firm offering the subcontract.” Foreign outsourcing is measured as the share of imported materials in total materials use (IMP_M). Our data on trade status includes the share of exports in total sales (EXP) and the share of foreign firm ownership (FDI). The plants are further distinguished by industry (apparel, textile) and region (East Anatolia, South-East Anatolia, Central Anatolia, Black sea, Aegean, Marmara, and Mediterranean).⁵

Our data also include revenues from output production and expenditures on labor, capital, intermediate material, and energy inputs, with changes in output and materials inventory stocks taken into account.⁶ The nominal values of output and materials inputs are divided by their corresponding price deflators, also included in the data, to derive real or “constant dollar” quantities in 1987 prices. The quantity of labor is measured as total production hours, and its price implicitly computed as expenditures divided by this quantity (separately for technical and administrative workers and production workers). The stock of capital is computed by cumulating gross investment data using the perpetual inventory method, deflated by a capital price index and adjusted for depreciation.

Summary statistics showing relative outsourcing shares overall and by trade and ownership status are presented in Table 1. Note first that significant amounts of both inputs and outputs are subcontracted in these industries – about 13.5 and 17.5 percent respectively – although only 1.5 percent of inputs are imported. The patterns for exporting versus non-exporting plants show that non-exporters produce an even greater share of their

⁵ Due to limited observations for the East Anatolian region we combined it with the Southeast Anatolian region and used only six region dummies.

⁶ Further details about the construction of these data are contained in Yasar and Paul (2007a).

output by contract – by nearly a factor of four. The shares of all outsourcing channels are larger also for foreign owned plants, with input and output outsourcing shares nearly 50 percent and the import share three times as large.

Performance Premia for Outsourcing Plants

Insights about the performance implications of outsourcing for the plants in our dataset are evident from regressions of performance indicators for plants with different outsourcing combinations on time, size (employment), and regional dummy variables, presented in Table 2.⁷ These measures show the average percentage differences in the dependent variable between plants in each outsourcing category and plants that do not engage in outsourcing activity, conditional on these factors. The dependent variables are labor productivity (*LProd*), the levels of wages and employment (*WAGE*, *EMP*), the amount of administrative or technical employees (*LADM*, *LTECH*), and the ratios of capital equipment and investment to employment (*K/EMP*, *INV/EMP*).

First note that about 23.8 percent of the plants in our data did not import materials *or* subcontract inputs or outputs. The largest percentage of plants is input-only subcontractors, at 27.2 percent, and about 15 percent were output-only subcontractors. However, 23 percent of the plants subcontracted both inputs and outputs. Only 2.1 percent of plants imported materials without carrying out other forms of outsourcing, but about 4 and 5 percent, respectively, subcontracted inputs or outputs as well as importing inputs.

The parameter estimates reported in Table 2 show that input subcontracting and importing plants are more productive, as well as more skilled labor- and capital-intensive than the control plants, particularly compared to output subcontracting plants. For

⁷ The regressions in which the dependent variable is employment or is on a per employee basis do not include the size variable.

example, labor productivity is 64 percent higher for plants that subcontract inputs and more than twice as high for plants that also import. By contrast, plants that subcontract output have 85 percent lower labor productivity. This is consistent with higher wages, size (*EMP*), and technical/administrative labor- and capital-intensity for these plants.⁸

However, further evaluation of outsourcing productivity patterns that recognizes interactions among the many plant level characteristics we can represent with our data requires estimating a structural model of production processes.

Productivity Differentials Between Starters and Non-Starters

Before moving to such a model, it is useful to consider whether the plants with better performance select into subcontracting relationship or subcontracting leads to higher productivity. Self-selection is based on the premise that only the most productive firms are able to enter the subcontracting relationship (Antras and Helpman, 2003). If outsourcing instead leads to higher productivity, firms that “start” outsourcing should experience productivity increases compared to non-nonstarters.

To examine these hypotheses, we compare the productivity gaps between non-starters and outsourcing starters before and after outsourcing.⁹ If self-selection is prevalent, the productivity of outsourcing starters will be higher than that of the non-starters in year t-1 (prior to outsourcing). If outsourcing generates productivity growth, we should see an increase in the gap between the productivity of outsourcing starters and non-

⁸ It is also consistent with the asymmetry found by Taymaz and Kilicaslan (2005) that they interpret as an indication that an “unequal” relationship exists between clients and subcontractors. That is, plants that offer subcontracts are more productive/skill plants and the reverse is true for plants that receive subcontracts.

⁹ Clerides, Lach, and Tybout (1999), Bernard and Jensen (1999), and Aw, Chung, and Roberts (2000) use similar approach to analyze the importance of self-selection and learning-by-exporting on the productivity differences between firms.

starters after outsourcing begins in year t . That is, the gap between the productivity of the starters and the non-starters in subsequent years will increase in favor of the starters.

To carry out these comparisons, we first define two groups of plants (starters and non-starters) as illustrated in the following table, for the plants that subcontract inputs (SUB_I), outputs (SUB_O), and materials (IMP_M) in the international market.

	t-1	t+1
Starters	No Outsourcing	Outsource
Non-Starters	No Outsourcing	No-Outsourcing

We then test whether outsource starters were more productive than non-starters before outsourcing took place, and compare the post-outsourcing productivity of the two groups to test whether the initial differential narrows, widens, or is unchanged.

The test results are shown in Table 3. Column 1 shows the percentage differences in labor productivity between outsourcing starters and non-starters in year $t-1$ (a year before outsourcers started to outsource). These estimates show that plants that started to outsource internationally in year t had about 36 percent higher labor productivity on average, prior to outsourcing, than those that did not do so. Similarly, plants that started to outsource inputs domestically had about 29 percent higher labor productivity on average prior to outsourcing than the control plants. However, plants that started to outsource outputs domestically had about 16% lower productivity on average than those that did not.

These results are consistent with the self-selection hypothesis that plants that begin outsourcing already have different productivity levels than plants that do not. In particular, they are consistent with the Antras and Helpman (2004) suggestion that if the fixed cost of outsourcing internationally is larger than outsourcing domestically, only the most

productive firms choose to outsource internationally.¹⁰ Firms that chose to outsource inputs domestically were also more productive, but somewhat less so.

Column 2 presents the change in the productivity differential in year t+1 (a year after outsourcers started to outsource). These measures show that the initial differential between the groups of plants widens after outsourcing takes place. The estimated increase in the productivity differential from t-1 to t+1 is 14.2, 9.4, and 5.3 percent for the plants that engage, respectively, in international outsourcing, domestic input subcontracting and domestic output outsourcing. Thus, the plants that choose to outsource increase their relative productivity, although the change in the productivity differential is only statistically significant for the plants that engage in international outsourcing.

Production Processes and Outsourcing

Further evaluating the relationships between outsourcing and productive processes, including input composition and trade, requires a production model that recognizes interactions among own and outsourced production factors. For this purpose, we assume production processes for the plants in our dataset can be represented by a (flexible) transformation function $\theta = F(\mathbf{Y}, \mathbf{X}, \mathbf{R}, \mathbf{T})$, where \mathbf{Y} is a vector of outputs, \mathbf{X} is a vector of inputs, \mathbf{R} is a vector of firm characteristics, and \mathbf{T} is a vector of (external) shift variables. By the implicit function theorem, if $F(\mathbf{Y}, \mathbf{X}, \mathbf{R}, \mathbf{T})$ is continuously differentiable and has non-zero first derivatives with respect to one of its arguments it may be specified (in explicit form) with that argument on the left hand side of the equation. Using our one output, Y , as our left hand side variable, the transformation function becomes the production function

¹⁰ For an excellent review of this literature see Helpman (2006).

$Y=G(\mathbf{X},\mathbf{R},\mathbf{T})$ representing the most output technologically producible from the given input vector, plant characteristics, and external conditions.¹¹

Recognizing input and output subcontracting as production factors permits a detailed representation of the productive and input composition implications of outsourcing. Input subcontracting implies domestic outsourcing of activities that otherwise would be carried out “in house” using the firm’s own inputs. Output subcontracting entails production for other companies of specific, potentially less skilled labor intensive, products. Importing intermediate materials involves outsourcing of foreign technology. Based on a flexible production function, the productivity variations associated with these forms of outsourcing can be characterized as shifts and twists in the (technological) production frontier.

Specifically, we include the outsourcing variables as \mathbf{R} vector components; the shares of a plant’s inputs and output that are subcontracted (SUB_I, SUB_O) and the share of imported materials in total materials use (IMP_M) become our input, output, and international outsourcing variables in \mathbf{R} . The \mathbf{R} vector also includes our trade variables – the share of exports in total sales (EXP), the share of foreign firm ownership (FDI), and licensing of foreign technology (LIC). In addition, we recognize the substitution of intermediate (processed) materials (M) for value-added (processing) inputs as an indicator of outsourcing. Such outsourcing increases the share of M relative to labor (technical/administrative and non-technical labor, L_T and L_N), capital (K) and energy (E),

¹¹ Note that theoretically such a model does not suggest that the arguments of the function “cause” the left hand side variable, since potentially all the arguments of the function except the external shift variables are endogenous. They indicate, given the right hand side variables, what output technically could be produced.

which are our components of the \mathbf{X} vector.¹² Variables in the \mathbf{T} vector are a time trend (t) and industry and region dummy variables (D_I, D_R). The production function embodying the production contributions of all these productive factors thus has the general form $Y = G(M, L_T, L_N, E, K, D_I, D_R, EXP, FDI, LIC, SUB_I, SUB_O, IMP_M, t)$.

The relationships between outsourcing and both productivity and input composition, including labor composition (L_T versus L_N) and trade (EXP, FDI), can be measured through first and second order elasticities of this function. For example, the relative (technological) productive contributions of inputs are reflected by the first-order output elasticities $\varepsilon_{Y, X_j} = \partial \ln Y / \partial \ln X_j$ for $j = (M, L_T, L_N, K, E)$. Further, complementarity or substitutability between, e.g., unskilled labor and intermediate materials, are reflected by second-order elasticities such as $\varepsilon_{M, L_N} = \partial^2 \ln Y / \partial \ln M \partial \ln L_N$ (or equivalently $\varepsilon_{L_N, M} = \partial^2 \ln Y / \partial \ln L_N \partial \ln M$, by Young's theorem). Such an elasticity allows us to evaluate whether additional materials use implies a lower or higher (proportional) marginal product for unskilled labor, and thus whether processing is "outsourced" by increased M .

More direct domestic and foreign outsourcing relationships are represented by output elasticities with respect to the input and output subcontracting and imported materials variables. For example, the productive implication of input subcontracting is computed as the first-order elasticity $\varepsilon_{Y, SUB_I} = \partial \ln Y / \partial \ln SUB_I$ reflecting a shift in the production frontier associated with a higher SUB_I share. If $\varepsilon_{Y, SUB_I} > 0$, plants with more SUB_I produce more output for a given input vector, industry, year, and region.

¹² For example, if purchased materials or services substitute for processing by unskilled labor, increasing intermediate materials use will have a depressing effect on the marginal product (and thus demand and wage) of unskilled labor.

Second-order elasticities provide further insights about these technological relationships. For example, the cross elasticity $\varepsilon_{\text{SUBI,EXP}} = \partial^2 \ln Y / \partial \text{SUB}_I \partial \text{EXP}$ shows whether the productivity associated with outsourcing is greater or less for exporting firms. By Young's theorem this elasticity is equivalent to $\varepsilon_{\text{EXP,SUBI}} = \partial^2 \ln \ln Y / \partial \text{EXP} \partial \text{SUB}_I$, which can be interpreted as showing whether the productivity associated with exporting is greater or less for input subcontracting firms.¹³

Linkages between outsourcing and input composition are also captured by (symmetric) second-order elasticities. For example, because the output elasticity $\varepsilon_{Y,LT} = \partial \ln Y / \partial \ln L_T$ represents the productive contribution of skilled labor, the second-order elasticity $\varepsilon_{LT,SUBI} = \partial^2 \ln Y / \partial \ln L_T \partial \text{SUB}_I$ reflects whether plants with more input subcontracting have higher ($\varepsilon_{LT,SUBI} > 0$, complements) or lower ($\varepsilon_{LT,SUBI} < 0$, substitutes) skilled labor shares, all else equal. If input subcontracting is, say, complementary with skilled labor, it enhances the employment and wages of skilled workers. Conversely, a positive value of $\varepsilon_{\text{SUBI,LT}} = \partial^2 \ln Y / \partial \text{SUB}_I \partial \ln L_T$ indicates that plants with greater skilled labor intensity gain more from outsourcing through input subcontracts. Such a relationship for foreign outsourcing, or imported materials – $\varepsilon_{LT,IMP_M} = \partial^2 \ln Y / \partial \ln L_T \partial \text{IMP}_M = \partial^2 \ln Y / \partial \text{IMP}_M \partial \ln L_T > 0$ – may similarly be interpreted as a trade-bias toward skilled labor (relative to unskilled labor if the impact is smaller or reversed for L_N), as found by Feenstra and Hanson (1996, 1999).

¹³ That is, firms may “learn by exporting” (Bernard and Jensen, 1995). The idea from this literature is that through exporting firms learn about and adopt international best practice production methods, receive feedback from international clients and competitors that may improve product offerings, and benefit from other knowledge spillovers or externalities.

Empirical Implementation of the Production Function Model

For estimation of our production model we approximate the production function by a translog form. This flexible function includes interactions or cross-effects among all its arguments (because it is a second order approximation), so it recognizes different productive relationships of outsourcing variables for different types of plants. We estimate the function using a semi-parametric empirical model based on Olley and Pakes (1996)¹⁴ to control for problems associated with self selection and simultaneity biases.¹⁵

This approach assumes that a plant chooses its variable inputs conditional on beginning of the period state variables (a productivity indicator, Ω_{it} , and the existing capital stock, K_{it}),¹⁶ that expected productivity and profits are functions of these state variables, and that Ω_{it} follows a first-order Markov process.¹⁷ Plants decide whether to remain in or exit the market by comparing their expected productivity to some threshold, subject to their state variables. Their capital investment decisions also depend on the state variables. A plant that experiences a positive productivity shock in period $t-1$ is thus likely to stay in the market and to invest more in period t .

¹⁴ The use of this model to control for these problems with respect to trade variables is supported by comparisons of Olley-Pakes estimates to those from correlation analysis, OLS, quantile regression, and matching models in Yasar and Paul (2007b, 2008).

¹⁵ We have also tried instrumental variables approaches to control for endogeneity of trade and outsourcing variables (Baltagi, 2001, Holtz-Eakin, Newey and Rosen, 1988, Arellano and Bond, 1991, Arellano and Bover, 1995, Blundell and Bond, 1998, 2000, Baum et al., 2003). GMM models using lagged values of the trade and outsourcing variables as instruments generated similar results to the Olley-Pakes model – somewhat higher productive contributions of the instrumented variables than for OLS. However, the Sargan test for overidentifying restrictions suggested that these are poor instruments. The Olley-Pakes results are thus quite robust – they imply slight OLS biases in the direction one would expect – and control for selection bias in addition to simultaneity, so it is our preferred econometric specification.

¹⁶ We have also treated the outsourcing and trade variables as state variables in a model without interacting them with the inputs and each other.

¹⁷ Alternatively, estimation could be carried out using the Levinsohn and Petrin (2003) approach, which uses intermediate inputs instead of investment to control for correlation between inputs and the unobserved productivity shock, and thus limits the problems associated with lumpy investment. Our capital input, however, is computed from investment series, thus investment data is not a problem for our data.

The translog production function relating output production to inputs, the state variables, and other functional arguments, and with an error structure consistent with the Olley-Pakes assumptions, can be written as:

$$\begin{aligned} \ln Y_{it} = & \beta_0 + \sum_j \beta_j \ln X_{jit} + \beta_K \ln K_{it} + \beta_t t + \sum_j \beta_{jt} \ln X_{jit} t + \beta_{kt} \ln K_{it} t + \sum_j \beta_{jK} \ln X_{jit} \ln K_{it} + \sum_m \beta_m R_{mit-1} \\ & + \sum_j \beta_{mK} R_{mit-1} \ln K_{it} + \sum_m \sum_j \beta_{mj} R_{mit-1} \ln X_{jit} + \sum_g \beta_g D_{git} + 0.5[\sum_j \sum_p \beta_{jp} \ln X_{jit} \ln X_{pit} + \beta_{KK} \ln K_{it}^2] \\ & + \Omega_{it} + \eta_{it} \end{aligned} \quad (1)$$

where i denotes plant, t time period, j variable inputs ($j=L_T, L_N, E, M$), m the outsourcing and trade variables, and g the regions and industries. η_{it} is a random measurement error.

Because the inputs are correlated with the productivity shock, OLS estimates of equation (1) are inconsistent and subject to simultaneity bias. Further, selection bias arises because a plant with higher levels of state variables will expect higher profits and have less incentive to exit. The Olley and Pakes estimation method accommodates these problems in two steps.

First, assuming that future productivity is increasing with respect to Ω_{it} , so

$\Omega_{it} = I_{it}^{-1}(I_{it}, K_{it}) = g_t(I_{it}, K_{it})$ with $\partial g_t / \partial I_{it} > 0$, (2) becomes:

$$\begin{aligned} \ln Y_{it} = & \beta_0 + \sum_j \beta_j \ln X_{jit} + \beta_t t + \sum_j \beta_{jt} \ln X_{jit} t + \beta_{kt} \ln K_{it} t + \sum_j \beta_{jK} \ln X_{jit} \ln K_{it} + \sum_m \beta_m R_{mit-1} \\ & + \sum_j \beta_{mK} R_{mit-1} \ln K_{it} + \sum_m \sum_j \beta_{mj} R_{mit-1} X_{jit} + \sum_g \beta_g D_{git} + 0.5[\sum_j \sum_p \beta_{jp} \ln X_{jit} \ln X_{pit}] \\ & + \phi(\ln I_{it}, \ln K_{it}) + \eta_{it}, \end{aligned} \quad (2)$$

where $\phi(I_{it}, K_{it}) = \beta_0 + \beta_K K_{it} + 0.5[\beta_{KK} K_{it}^2] + g_t(\ln I_{it}, \ln K_{it})$ is a third-order polynomial series in (the logs of) investment and capital input.¹⁸ ϕ controls for unobserved productivity, so the error term is not correlated with the inputs and (2) does not suffer from simultaneity bias.

¹⁸ Petrin, Poi, and Levinsohn (2004) suggested using third order polynomial series to approximate unknown functions of this type.

Second, to control for selection bias, the probability of the plant staying in the market is estimated by a probit model, using a polynomial series in lagged investment and capital stock. The resulting model:

$$\begin{aligned} \ln Y_{it} - \sum_j \hat{\beta}_j \ln X_{jit} - \hat{\beta}_t t - \sum_j \hat{\beta}_{jt} \ln X_{jit} t - \hat{\beta}_{kt} \ln K_{it} t - \sum_j \hat{\beta}_{jk} \ln X_{jit} \ln K_{it} - \sum_m \hat{\beta}_m R_{mit-1} \\ - \sum_j \hat{\beta}_{mk} R_{mit-1} \ln K_{it} - \sum_m \sum_j \hat{\beta}_{mj} R_{mit-1} X_{jit} - \sum_g \hat{\beta}_g D_{git} - 0.5[\sum_j \sum_p \hat{\beta}_{jp} \ln X_{jit} \ln X_{pit}] \\ = \beta_K \ln K_{it} + \beta_{KK} \ln K_{it}^2 + g(\hat{\phi}_{t-1} - \beta_K \ln K_{it-1} - \beta_{KK} \ln K_{it-1}^2, \hat{P}_{it}) + \xi_{it} + \eta_{it}, \end{aligned} \quad (3)$$

where \hat{P}_{it} is the survival probability and $g(\cdot)$ is approximated by a second-order polynomial in $\hat{\phi}_{t-1} - \beta_K \ln K_{it-1} - \beta_{KK} \ln K_{it-1}^2$ and \hat{P}_{it} , controls for unobserved plant differences and sample selection as well as simultaneity.¹⁹

Estimated Production Structure Patterns

The parameter estimates of equation (3), estimated with all outsourcing and trade variables lagged by one period as another control for endogeneity and input cross-effects with the trade variables omitted due to overall insignificance, and with significant cross-effects of outsourcing variables in bold font, are presented in Table 4.²⁰ The associated first-order output elasticities, evaluated on average across the full sample,²¹ are reported in Table 5.

¹⁹ To evaluate the robustness of our model to considering the outsourcing and trade variables endogenous we alternatively included them for estimation as state variables, based on a second order polynomial series in investment, capital and these variables, for both steps. We did not interact the trade and outsourcing variables with the input variables because convergence problems arise from the increased number of nuisance parameters. Estimation without the interactions, however, did not substantively change the results. The only difference was that the coefficient on SUB_o became positive and insignificant. The order of the productivity effect of other trade and outsourcing variables were consistent with those in Table 4.

²⁰ We pooled the apparel and textile industries but tested to see whether coefficients for the two industries varied by interacting the industry dummy with inputs, trade and outsourcing variables. The test results, with P-value of 0.329, show that the regression coefficients do not significantly differ by industry. Although textile firms are generally somewhat larger and more capital-intensive than apparel firms, it is very common in the literature to pool these industries since they have similar characteristics.

²¹ The standard errors are thus computed using the “delta method,” a generalization of the Central Limit Theorem derived using the Taylor series approximations. We implement the delta method using TSP, which utilizes the parameter estimates from our model and their corresponding variance covariance matrix to evaluate the elasticities at average values of the inputs.

First note that from Table 5 that the estimated output elasticities show significantly more (total factor) productivity for firms that subcontract inputs and import materials, but less productivity for firms the subcontract outputs, consistent with the results found for the premia and labor productivity analyses discussed above. The additional insights to be gained from the estimates of the production structure involve the underlying relationships between the input “contributions,” exhibited by the overall output elasticities for the inputs, and the outsourcing and trade variables.

Technological substitutability or complementarity of intermediate materials with other inputs is evident from the M cross-terms β_{Mj} in Table 4, which are equivalent to the elasticities $\varepsilon_{M,X_j} = \partial^2 \ln Y / \partial \ln M \partial \ln X_j$ with the second-order logarithmic functional form. The negative β_{Mj} estimates indicate that M substitutes for all other inputs. This might be expected since increasing intermediate materials conceptually involves reductions in value added inputs, as well as inputs like energy that likely track K rather than M use (Berndt and Wood, 1979). The largest (in absolute value) estimate is for L_N , at -0.066, followed by that for L_T , at -0.042, so increasing M is primarily associated with reduced labor demand, and for unskilled (more likely used for material processing) relatively more than skilled labor.

Input biases more directly associated with outsourcing or contracting are reflected by the estimated outsourcing cross-effects $\beta_{j,SUBI}$, $\beta_{j,SUBO}$ and $\beta_{j,IMPM}$ (for all inputs j), which imply the second-order elasticities such as $\varepsilon_{j,SUBI} = \beta_{j,SUBI}$ capturing input composition effects. For example, the parameter estimate $\beta_{LT,SUBI}$ represents the symmetric elasticities $\varepsilon_{LT,SUBI} = \partial^2 \ln Y / \partial \ln L_T \partial SUB_I = \partial^2 \ln Y / \partial SUB_I \partial \ln L_T = \varepsilon_{SUBI,LT}$. The significantly (at the 1 percent level) positive $\beta_{LT,SUBI}$ estimate shows that a higher share of subcontracted inputs implies greater administrative and technical (skilled) labor intensity.

However, the significantly negative (at the 5 percent level) $\beta_{LN,SUBI}$ estimate shows that this is also associated with less unskilled labor use. Note also that input subcontracting is significantly related only to the labor shares; all other cross-effects are insignificant.

This pattern of SUB_I-L_T complementarity and SUB_I-L_P substitutability implies that subcontracting inputs reduces in-house “production” of lower-productivity and -skill activities or processes (e.g., those provided by unskilled production line workers) or services (e.g., janitorial workers), rather than services of skilled workers (e.g., legal or accounting services). It also may be that more input subcontracting requires administrative and technical expertise due to greater required supervision or support of contractors.

By contrast, higher levels of subcontracted *output* imply significantly less reliance on skilled labor, supporting the notion that plants that subcontract their output are more “low-tech.” Output subcontracting is also associated with less intermediate materials use (suggesting more reliance on primary rather than processed materials), and a greater energy share (perhaps required for the additional processing). The lower M and L_N shares for output subcontracting plants underlie the overall negative SUB_O output elasticity.

More imported materials similarly implies lower M and L_N intensity, but not significantly so. The positive output elasticity for IMP_M is in fact driven by the first order coefficient β_{IMP_M} ; imports have little effect on input composition. That is, the primarily negative input biases are too small to counteract the strong positive first order effect.

Further, linkages of trade factors with outsourcing vary by outsourcing channel. There is no significant relationship between the productivity implications of SUB_I and trade status (EXP , FDI , or IMP_M). However, the interactions between SUB_O and these trade variables are significant, with those for EXP negative and for FDI and IMP_M positive.

These estimates imply that plants that import materials or have foreign ownership have higher productivity than other output contracting plants, but those that export actually exhibit worse productivity. Conversely, the (positive) productivity associated with trade factors, evident from their output elasticities, is lower for output subcontracting plants that export and higher for those with foreign ownership or that import.

Concluding Remarks

In this paper we have used three types of analyses – premia regressions, analysis of productivity and productivity growth gaps between outsourcing “starters” and “non-starters,” and estimation of a translog production function model by procedures that accommodate simultaneity and selection issues – to measure the productivity and input composition implications of domestic and foreign outsourcing. All three approaches show that higher shares of imported materials and subcontracted inputs are associated with significantly greater performance, including higher labor and total factor productivity. Analysis of labor productivity gaps also reveals both self selection of more productive plants into (input and foreign) outsourcing and increased relative productivity after beginning to outsource. The reverse is true for output outsourcing, which is associated with lower productivity levels.

The production function estimations also show significant substitution between intermediate materials and value added inputs, especially for unskilled labor, implying that productive plants tend to outsource processing activities to reduce capital and particularly labor use. In contrast, although foreign outsourcing (importing materials) is associated with greater plant productivity, it does not imply substantive input composition changes or biases. Further, the higher productivity associated with input subcontracting is driven by a

strongly positive skilled labor bias; firms that subcontract more inputs are more skilled-labor-intensive (SUB_I and L_T are complements). The reverse is true for unskilled labor. This supports the suggestion in the literature that firms that subcontract inputs tend to be more productive high-skill firms, even controlling for other measurable factors by our estimation of the production technology.

In turn, the lower productivity for plants that outsource or subcontract outputs is associated with significantly lower skilled labor and purchased intermediate materials intensity, supporting the suggestion in the literature that output subcontracting firms tend to be lower productivity/skill firms, all else constant. The productive implications of output subcontracting vary, however, depending on the plant's international linkages. Plants that subcontract output but also have a foreign share or import are more productive, and exporters are even less productive than those without any foreign linkages. This is consistent with suggestions in the literature that plants associated with multinational corporations (FDI plants) tend also to receive subcontracts from those corporations, although the negative (but insignificant) $FDI-SUB_I$ cross-effect suggests that this is not true for input subcontracting.

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Table 1. Shares of SUB_I , SUB_O , and IMP_M in for Different Group of Plants (%)

	SUB_I	SUB_O	IMP_M
Overall	13.49	17.45	1.48
Non-Exporters	11.63	30.64	0.32
Exporters	14.69	8.92	2.22
Domestic	13.32	17.19	1.39
Foreign	19.64	26.56	4.50

Table 2. Percentage Differences between Groups

Dependent variable	SUB_I (dummy)	SUB_O (dummy)	IMP_M (dummy)	SUB_I & SUB_O	SUB_I & IMP_M	SUB_O & IMP_M
Ln L_{Prod}	0.643 (0.039)***	-0.852 (0.046)***	0.632 (0.119)***	0.079 (0.040)**	1.036 (0.064)***	0.656 (0.065)***
Ln $WAGE$	0.146 (0.019)***	-0.084 (0.022)***	0.24 (0.058)***	0.088 (0.019)***	0.413 (0.031)***	0.295 (0.032)***
Ln EMP	0.349 (0.037)***	-0.042 (0.043)	0.605 (0.112)***	0.535 (0.037)***	0.834 (0.060)***	1.258 (0.061)***
Ln L_{ADM}	0.664 (0.047)***	-0.368 (0.055)***	0.831 (0.141)***	0.544 (0.047)***	1.286 (0.076)***	1.544 (0.077)***
Ln L_{TECH}	0.094 (0.056)*	-0.019 (0.069)	0.210 (0.144)	0.170 (0.056)***	0.444 (0.082)***	0.62 (0.080)***
Ln K/EMP	0.323 (0.070)***	-0.294 (0.081)***	0.932 (0.208)***	0.465 (0.071)***	0.813 (0.113)***	1.023 (0.115)***
Ln INV/EMP	0.108 (0.096)	-0.552 (0.118)***	0.632 (0.273)**	0.108 (0.096)	0.588 (0.139)***	0.299 (0.136)**
Percentage of plants	27.2	15.2	2.1	23.0	4.8	3.9

Notes: (1) Robust standard errors are in parentheses. *Significant at the 10% level. ** Significant at the 5% level. ***Significant at the 1% level. (2) The independent variables for the different regressions include time, size, and region dummies. (3) The base group is the plants that do not engage in any of these activities.

Table 3. Average Productivity Differences between Starters and Non-starters

	Differential Pre-Outsourcing	Change in Differential Post-Outsourcing
SUB_I	0.294 (0.077)***	0.094 (0.067)
SUB_O	-0.162 (0.103)	0.053 (0.087)
IMP_M	0.359 (0.076)***	0.142 (0.068)**

Notes: (1) Robust standard errors are in parentheses. ** Significant at the 5% level. *** Significant at the 1% level. (2) The independent variables for the different regressions include size and region dummies.

Table 4. Production Function Estimates

Variables	Coefficients	Std. Error	Variables	Coefficients	Std. Error
β_M	0.236***	(0.047)	β_{SUBI}	0.502*	(0.267)
β_E	0.157***	(0.050)	$\beta_{M,SUBI}$	-0.043	(0.038)
β_K	0.134***	(0.026)	$\beta_{E,SUBI}$	-0.013	(0.048)
β_{LT}	0.147**	(0.061)	$\beta_{K,SUBI}$	-0.019	(0.038)
β_{LN}	0.406***	(0.074)	$\beta_{LT,SUBI}$	0.159***	(0.062)
$\beta_{M,M}$	0.152***	(0.007)	$\beta_{LN,SUBI}$	-0.104**	(0.071)
$\beta_{E,E}$	0.017*	(0.009)	β_{SUBO}	0.368**	(0.172)
$\beta_{K,K}$	0.003	(0.005)	$\beta_{M,SUBO}$	-0.053**	(0.026)
$\beta_{LT,LT}$	0.032**	(0.016)	$\beta_{E,SUBO}$	0.066**	(0.031)
$\beta_{LN,LN}$	0.077***	(0.020)	$\beta_{K,SUBO}$	0.012	(0.025)
$\beta_{M,E}$	-0.025***	(0.009)	$\beta_{LT,SUBO}$	-0.079*	(0.041)
$\beta_{M,K}$	-0.016***	(0.006)	$\beta_{LN,SUBO}$	-0.033	(0.048)
$\beta_{M,LT}$	-0.042***	(0.010)	β_{IMPM}	0.683	(0.913)
$\beta_{M,LN}$	-0.066***	(0.012)	$\beta_{IMPM,SUBI}$	0.312	(0.877)
$\beta_{E,K}$	-0.003	(0.006)	$\beta_{IMPM,SUBO}$	2.414**	(1.120)
$\beta_{E,LT}$	0.010	(0.009)	$\beta_{M,IMPM}$	-0.089	(0.174)
$\beta_{E,LN}$	-0.005	(0.012)	$\beta_{E,IMPM}$	0.182*	(0.100)
$\beta_{K,LT}$	0.014*	(0.008)	$\beta_{K,IMPM}$	-0.080	(0.106)
$\beta_{K,LN}$	-0.010	(0.010)	$\beta_{LT,IMPM}$	-0.035	(0.150)
$\beta_{LT,LN}$	0.007	(0.013)	$\beta_{LN,IMPM}$	-0.049	(0.179)
β_{LIC}	0.175**	(0.074)	β_T	0.098***	0.031
β_{EXP}	0.670***	(0.133)	β_{TT}	-0.028***	0.007
$\beta_{EXP,SUBI}$	0.293	(0.198)	$\beta_{APPAREL}$	-0.337***	(0.030)
$\beta_{EXP,SUBO}$	-0.488***	(0.223)	Agean	0.101	(0.092)
$\beta_{EXP,LP}$	-0.115***	(0.031)	Black Sea	0.022	(0.114)
β_{FDI}	0.793**	(0.392)	C. Anatolian	0.064	(0.098)
$\beta_{FDI,SUBI}$	-0.198	(0.293)	Marmara	0.116	(0.092)
$\beta_{FDI,SUBO}$	0.493***	(0.153)	Mediterranean	0.094	(0.119)
$\beta_{FDI,LP}$	-0.150*	(0.057)			

Notes: (1) ***Significant at the 1% level. **Significant at the 5 percent level. *Significant at the 10 percent level.

Table 5. Elasticities at the Mean Values Calculated by the Delta Method

Variables	Elasticity	T-Statistic
SUB _I	0.086	<i>1.66</i>
SUB _O	-0.092	<i>-1.80</i>
IMP _M	0.593	<i>2.46</i>
<i>M</i>	0.716	<i>73.21</i>
<i>L_T</i>	0.071	<i>6.37</i>
<i>L_N</i>	0.198	<i>12.05</i>
<i>K</i>	0.040	<i>2.24</i>
<i>E</i>	0.033	<i>3.58</i>
EXP	0.626	<i>4.67</i>
FDI	0.851	<i>2.250</i>
RTS	1.059	<i>25.54</i>