CPB Netherlands Bureau for Economic Policy Analysis

CPB Discussion Paper | 250

The Effects of Outsourcing on Firm Productivity Evidence from Microdata in the Netherlands

Jan Möhlmann
Henri L.F. de Groot

The effects of outsourcing on firm productivity

Evidence from microdata in the Netherlands

Jan Möhlmann
VU University Amsterdam

Henri L.F. de Groot
VU University Amsterdam; CPB Netherlands Bureau for Economic Policy Analysis;
Tinbergen Institute; Ecorys NEI

Abstract

International outsourcing is an important aspect of economic globalization. Since outsourcing leads to more specialization, it is expected to reduce production costs and to increase productivity. This study uses microdata on Dutch firms to investigate the effects of international and domestic outsourcing on firm productivity at the firm level. It is based on a unique survey on outsourcing covering the period 2001–2006. The survey allows us to distinguish between domestic and international outsourcing and between outsourcing of core and support activities. We study the effects of these different types of outsourcing on labour productivity and total factor productivity (TFP). The results show that, without adjusting for firm size, more productive firms are more likely to outsource. When we adjust for firm fixed effects, the results suggest that international outsourcing of core functions decreased TFP and domestic outsourcing of support functions increased TFP.

Keywords: outsourcing, firm productivity
JEL-codes: L24, D24

Acknowledgement: this paper benefited from comments on a previous version from Peter van Bergeijk, Frank den Butter, Steven Brakman, and participants of the conference 'Productivity and Internationalisation: A Micro-data approach' on 2 September 2010 in The Hague. All remaining errors are our own. Jan Möhlmann gratefully acknowledges financial support from Platform31 and the hospitality of CPB and CBS, where part of this research was carried out. Corresponding author: Jan Möhlmann, VU University Amsterdam, Department of spatial economics, De Boelelaan 1105, 1081 HV Amsterdam, j.l.mohlmann@vu.nl.

1 Introduction

Outsourcing is one of the driving forces behind the process of fragmentation and specialization of the production process. It involves buying intermediate goods or services, which were previously produced inside the firm, from a third party (Görg et al., 2008). This phenomenon is not new, as people in early times already realized that is was better to divide tasks rather than doing everything yourself. For example, a baker that decides to buy grain from a farmer instead of growing the grain himself is also outsourcing a task. However, it is relatively new that firms are outsourcing parts of their production process abroad. While outsourcing used to be a local or domestic phenomenon, technological advances in, for example, transportation methods, allowed firms to buy intermediate goods from other countries as well. Balassa (1967) and Findlay (1978) referred to this as vertical specialization. Krugman (1995) described this process as 'slicing up the value chain'. Besides internationally outsourcing the production of intermediate goods, it is also becoming more common to internationally outsource services. An often used example of this is the Indian call centre employee calling customers of American firms. This became possible due to a large decline of communication costs, caused by advances in information and communication technology.

Due to the displacement of jobs that is caused by outsourcing, outsourcing generally has a negative annotation, especially when it involves international outsourcing. Since most economic activity in developed countries comes from the service sector, the possibility of internationally outsourcing services increased the fear of job losses. While economic trade theory suggests that countries will not lose employment, even if another country has an absolute advantage in everything (Ricardo, 1817), outsourcing is also expected to have negative effects in the form of distributional effects and temporary unemployment.

On the other hand, outsourcing could increase the productivity of firms. There is a trade-off between production costs and transaction costs. Outsourcing could reduce the production costs, but it will increase external transactions costs, which are the result from dealing with a third party. Outsourcing could lead to an increase in firm productivity if it reduces production costs more than it increases transaction costs. Hence, outsourcing can become more attractive when the difference in production costs increases or when advances are made in transaction technology. Therefore, innovations that reduce transaction costs could make outsourcing more

attractive and increase productivity. Den Butter et al. (2008) also show that trade innovations can explain productivity at the national level.

Abraham and Taylor (1996) mention three main reasons that can explain why outsourcing can decrease production costs. The first reason is that a third party could potentially produce the intermediate cheaper than the firm itself, for example due to lower wages. This is particularly relevant for international outsourcing, as wages can differ substantially between countries. Abraham and Taylor also mention that even domestic outsourcing can reduce the wage bill, for example when the outsourcing firm is unionized and the contractor is not. The second reason is associated with the cyclicality of output. When a firm experiences cyclical output over time, it may not have enough capacity for the peak periods, since this implies having too much capacity in periods with less demand. Instead, the firm could choose to outsource part of the production process in the peak periods. The third reason is economies of scale. If for some part of the production process economies of scale apply, costs will be lower if all firms outsource this particular part to another party. For example, many small firms outsource their wage administration to specialized accountancy firms.

Grossman and Rossi-Hansberg (2008) model how offshoring (international outsourcing) has three effects: a productivity effect, a relative price effect and a labour supply effect. The productivity effect means that the costs of performing a set of tasks is reduced, resulting from lower production costs in the insourcing country.

Although there are sound theoretical arguments that support the idea that outsourcing could improve firm productivity, empirical research on this issue has been relatively limited (Geishecker et al., 2008). An important reason for this is the difficulty of measuring outsourcing. The studies that initially investigated the relationship between outsourcing and productivity used sectoral data and obtained mixed results. Examples are Egger and Egger (2006), using European data on manufacturing sectors, and Amity and Wei (2004), using data on US manufacturing sectors. Egger and Egger (2006) found a negative productivity effect of international outsourcing in the short run and a positive effect in the long run. Amiti and Wei (2004) found no impact of international outsourcing of materials and a positive impact of international outsourcing of services.

Since microdata became better available, several studies investigated the effect of outsourcing on the level of the firm. These studies are often based on the model by Melitz

(2003), which deals with firms that are heterogeneous in their levels of productivity. In this model firms need to invest before they know their own productivity, and they only enter the market if their productivity is sufficiently high. Additionally, only the most productive firms decide to export to foreign markets, because less productive firms are not able to recover the fixed costs associated with exporting. Outsourcing also requires a firm to incur fixed costs, for example because the firm needs to find a suitable supplier. Applying the Metliz (2003) model to outsourcing would therefore predict that only the most productive firms outsource. A similar model that is concerned outsourcing and firm productivity is the model by Antràs and Helpman (2004). Their model also assumes firms with heterogeneous productivity levels, while introducing the concept of incomplete contracts. Their model also predicts that only the most productive firms outsource internationally.

For an overview of previous empirical studies on outsourcing and productivity, see Olsen (2006). Although the results of these studies still vary, possibly due to differences in the country, sector, time period, or outsourcing measure, the majority of the studies seem to find either no statistically significant impact or a positive impact. For example, Girma and Görg (2004) used microdata for firms in the UK and found a positive effect of outsourcing on the level of productivity for chemical and engineering firms, but no impact of outsourcing on the growth of productivity. Görg and Hanley (2005) considered firms in Ireland, and found a positive impact on productivity of international outsourcing of materials and no significant impact of international outsourcing of services. These studies measure outsourcing by using the costs of (imported) intermediates of the firm.

This study uses a different approach, by using a survey that explicitly asks firms about their outsourcing activities. The advantage of this approach is that we can be fairly certain whether a firm indeed outsourced, whereas the measure based on the costs of intermediates of the firm can also be influenced by other factors. For example, price changes of intermediate inputs or capital and labour inputs can change the share of intermediate inputs in total inputs without any outsourcing activities. Furthermore, when firms produce multiple products that use a different composition of inputs, changing the product composition will also change the input composition. So when a firm increases its use of intermediate products relative to its use of capital and labour inputs, this does not necessarily indicate outsourcing. Another advantage of using a survey on outsourcing is that it gives information about the type of outsourcing. An

interesting distinction is the one between domestic and international outsourcing. Many studies focus on international outsourcing, while much less attention is given to domestic outsourcing. We can identify whether there is a hierarchy on the type of outsourcing as is implied by the Melitz (2003) model. We expect that the fixed costs are higher for international outsourcing than for domestic outsourcing and higher for domestic outsourcing than for keeping activities within the firm. In terms of the Melitz (2003) model this would imply that the most productive firms can outsource internationally while the least productive firms do not outsource. Additionally, the survey allows us to distinguish between outsourcing of core and of support activities.

A study that uses data from the same survey, but for German firms, is Wagner (2011). He found that firms that outsourced internationally were larger and more productive. He also shows that these firms were already more productive before the period of outsourcing, indicating a selection effect. This result is also found in the literature on exporting, which suggests that such a selection effect does indeed explain why exporting firms are more productive than non-exporting firms. See, for example, a literature survey by Bernard et al. (2007). An example of a survey-based study on international outsourcing of Dutch firms is Van Gorp (2010). She used a survey that was held in 2009 and included about 700 Dutch firms of which 55 percent employed more than 100 full-time equivalents. These firms were not linked to productivity data from Statistics Netherlands, but the survey did include some questions on whether the firm considered the outsourcing to be successful. About half of the firms responded that they largely or completely achieved their objectives on cost savings.

This study contributes to the existing literature by using microdata for Dutch firms. It tests the hypothesis that firms that outsource are more productive, which would follow from applying the Melitz (2003) model to outsourcing. Additionally, we also attempt to determine whether there exists a causal relationship from outsourcing to productivity. Another contribution of this study is that it distinguishes between domestic and international outsourcing. Many previous studies focus only on international outsourcing. Furthermore this paper also distinguishes between outsourcing of core and support activities. The structure of this paper is as follows. The next section gives an overview of the microdata with some stylized facts. Section 3 explains our indicators for productivity. Section 4 presents the results for cross-sectional estimations and for fixed effects estimations. The main conclusions will be discussed in Section 5.

2 Data description

2.1 Outsourcing data

One of the reasons for the relatively small amount of empirical research on outsourcing and productivity is the lack of data on outsourcing. This study uses a survey by Eurostat, which was deployed in twelve European countries in 2007. Some descriptive statistics of this survey for Denmark, Finland, Norway, the Netherlands, and Sweden are published by Statistics Denmark et al. (2008).[1] This study only uses the data that were obtained from firms in the Netherlands, which were kindly provided by Statistics Netherlands (CBS). The Dutch survey was sent to 1,503 firms in the non-financial business economy which had at least 100 employees in 2007 and received 1,002 responses.[2]

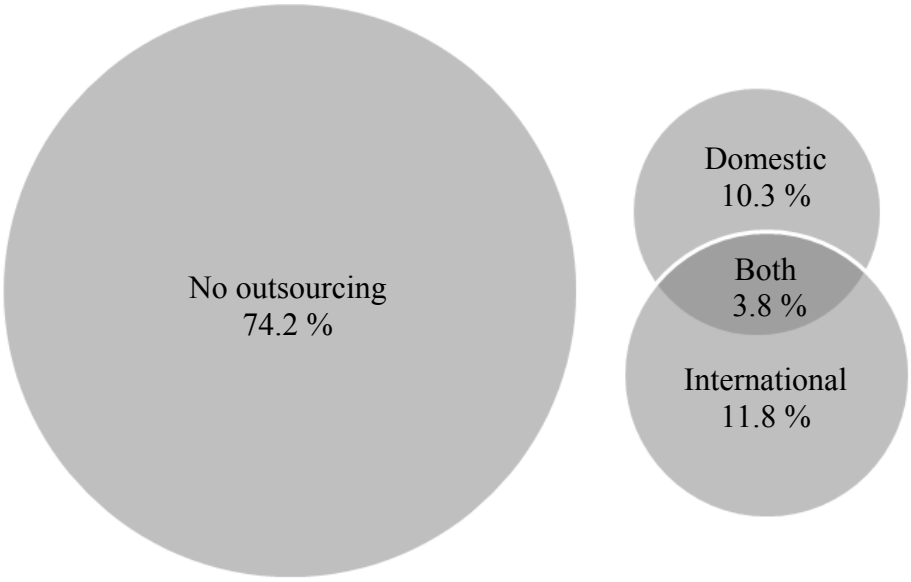
The survey asked firms whether they had outsourced in the period 2001–2006. The phrasing of the question was prescribed by Eurostat as: *What type of functions has your enterprise sourced in the period 2001–2006?* For each activity firms had to check a box for domestic outsourcing, for international outsourcing, or for no outsourcing. The exact survey question as it was asked in the Dutch survey is included in Appendix A. The survey question made it possible to distinguish between domestic and international outsourcing. This is an interesting distinction because many previous studies on outsourcing focused only on international outsourcing. Additionally we could distinguish between outsourcing of core business functions and several types of support business functions. Note that the measure of outsourcing that is used in this study is not a perfect measure. It is only a binary measure which is measured over a relatively large period of time. We only know that a firm outsourced between 2001–2006, but not when it actually took place. This makes identification of the effect more difficult. Additionally, we do not know if the firm outsourced once in this period or multiple times, or what the magnitude of outsourcing was.

[1] It is possible that some descriptive statistics reported in this chapter differ slightly from those reported by Statistics Denmark et al. (2008). These differences can occur because the latter study used weights based on sector and size class, while this study does not.

[2] The 1,503 firms were selected from a population of 4,633 firms that met the selection criteria. They were selected using stratified sampling, using twelve strata based on size (100–200 employees, 200–500 employees, more than 500 employees) and activity (high tech manufacturing, medium and low tech manufacturing, knowledge intensive business services, other activities). See also Statistics Denmark et al. (2008).

Most of the firms (74.2 percent) did not outsource any activities between 2001 and 2006. International outsourcing (15.6 percent) occurred slightly more often than domestic outsourcing (14.1 percent). Figure 1 contains a Venn diagram that shows the share of firms that outsourced domestically, internationally, or both.

Figure 1. Outsourcing shares by destination



The share of firms that outsourced domestically and internationally are also shown for each business function in Table 1. The number of firms that outsourced the same activity both domestically and internationally is negligible. Second, Table 1 suggests that firms that outsource an activity that is considered to be part of their core business, are more likely to outsource internationally (9 percent) than domestically (4 percent). For almost all types of support activities, the share of firms that outsourced them domestically is larger than the share of firms that outsourced them internationally. The most popular type of support activities to outsource were ICT services (6 percent domestic and 4 percent international).

We combined the answers on the questions about support business functions in order to create four different binary measures for outsourcing: domestic outsourcing of core functions, domestic outsourcing of support functions, international outsourcing of core functions and international outsourcing of support functions. The small number of firms that outsourced both domestically as well as internationally are included in both measures.

Table 1. Outsourcing shares by activity and destination (in percent)

	Only domestic	Only international	Both types
Core business functions:			
Production of goods and services for the market	4	9	1
Support business functions:			
Distribution and logistics	4	3	0
Marketing, sales and after sales services, including help desks and call centres	3	2	0
ICT services	6	4	0
Administrative and management functions	5	3	0
Engineering and related technical services	2	1	0
Research and development	1	2	0
Other types of functions	1	0	0

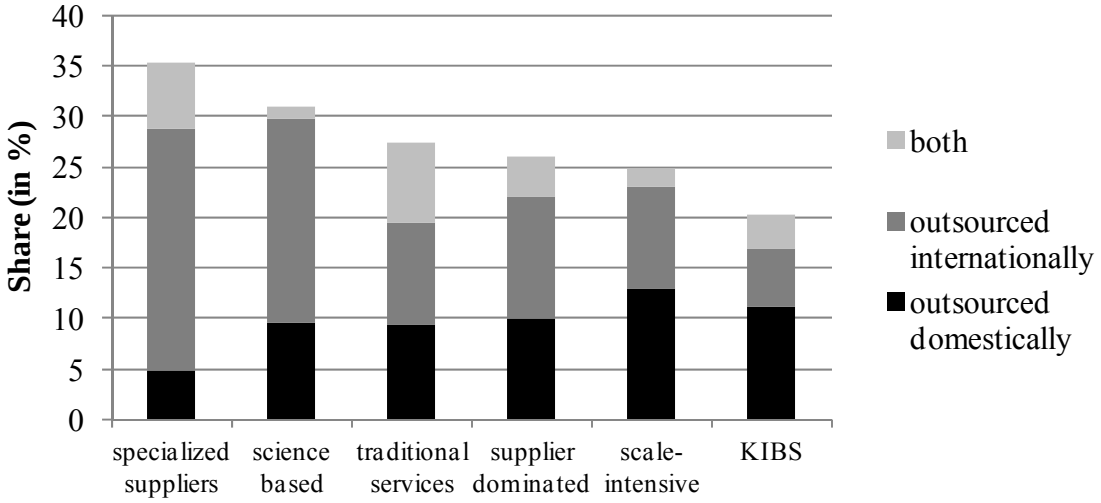
Table 2 gives an overview of these four types with the share of firms that have been engaged in each type of outsourcing in the period 2001–2006. This table confirms that core activities are most often outsourced internationally, while support activities are more often outsourced domestically. Domestic outsourcing of core functions is relatively rare, while the other three types of outsourcing are about equally common. In the period 2001–2006 about 26 percent of the firms outsourced at least some of its business functions. This percentage is lower than the sum of the four types in Table 2, because some firms were engaged in multiple forms of outsourcing. About 10 percent of the firms only outsourced domestically, 12 percent only outsourced internationally, and 4 percent did both. This means that about 16 percent of the firms outsourced internationally, which is a bit lower than the result from the survey by Van Gorp (2010), who found that about 29 percent of the respondents had outsourced internationally at least once in the period before 2009.

Table 2. Outsourcing shares of outsourcing variables (in percent)

		Location	
		Domestic	International
Type	Core	4.7	9.7
	Support	11.9	10.0

Figure 2 shows the share of firms that outsourced (internationally) for six sectors, which are based on the classification by Pavitt (1984). The Pavitt classification classifies sectors based on their sources of technology, requirements of the users, and appropriability regime (Pavitt, 1984). This classification contains eight sectors, which are defined in Table 3. Our dataset only contains firms that fall in six of these Pavitt sectors, since there are no firms from the mining and quarrying (primary) sector or from the financial intermediation (information intensive) sector.

Figure 2. Outsourcing shares, by Pavitt sector



Note: KIBS stands for knowledge-intensive business serivces

The ordering of the Pavitt sectors indicates that it is relatively difficult to outsource knowledge intensive business services (KIBS), while outsourcing in the specialized suppliers sector (which produces machinery and equipment) is relatively easy. This is consistent with the observation that the production process of goods is generally more fragmented than that of services. Outsourcing shares are also relatively low in scale-intensive sectors, which is consistent with the idea that outsourcing reduces the possibilities of benefiting from economies of scale.

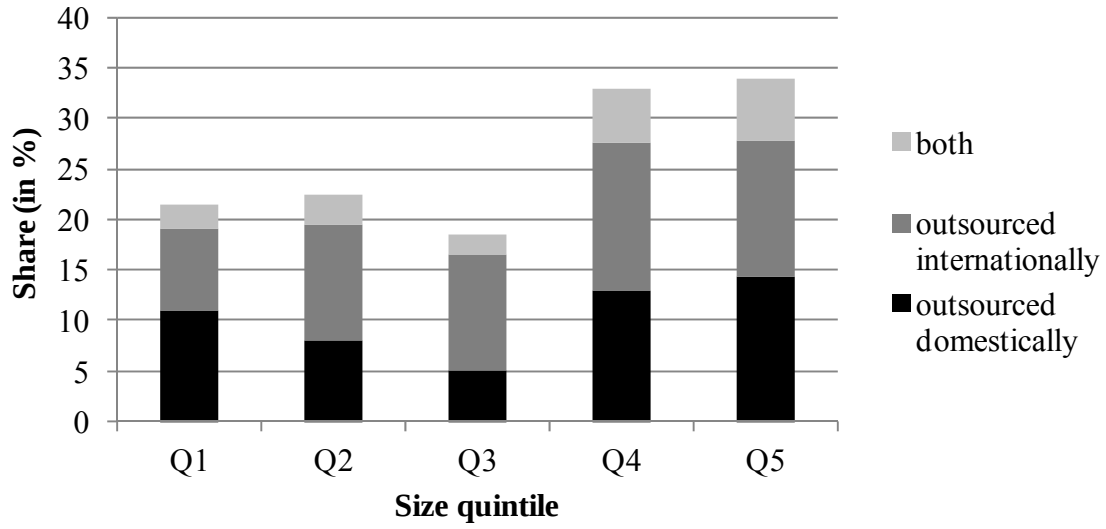
Table 3. Pavitt sectoral classification

Pavitt sector	Industries
Primary	Mining and quarrying
Science based	Chemical products
Specialized suppliers	Machinery and equipment
Scale-intensive	Food, beverages and tobacco; Metal products; Electricity, gas and water; Construction; Transport; Communication
Supplier dominated	Textile, clothing and leather products; Wood, paper and printing; Other manufacturing
Information intensive	Financial intermediation
Knowledge-intensive business services (KIBS)	Computer services; Other business services
Traditional services	Wholesale trade; Retail trade; Hotels and restaurants; Real estate and renting

Note: there are no firms from the primary sector or the information intensive sector in the outsourcing survey.

Figure 3 shows the shares for domestic and international outsourcing by size category. It shows the five quintiles based on the number of employees in 2007. It illustrates that larger firms are more likely to outsource, both domestically and internationally. Since these firms were already larger before the outsourcing period of the survey, it suggests a selection effect.

Figure 3. Outsourcing shares, by size quintiles



Note: size quintiles are based on the number of emloyees in 2007.

Table 4 also suggests a relationship between outsourcing and the export activities of firms. Firms that outsourced during the period 2001–2006 are more likely to export than firms that did not outsource. The information on exports is based on the production statistics. Since this also is a survey, the information on exports was not available for all firms in the outsourcing survey. We were able to match 723 of the firms in the outsourcing survey with at least one year of the production statistics. Table 4 shows the exporting and outsourcing status for these 723 firms. Most of these firms exported in at least one year (79.5 percent) and a minority of them outsourced (28.2 percent). For the group of firms that exported, the share of firms that outsourced was about 30 percent, while for the group of firms that did not export, the share of firms that outsourced was about 22 percent.

Table 4. Outsourcing and exporting shares

	Observations	Number of firms that outsourced	Share of firms that outsourced (in percent)
Firms that did not export	148	33	22.3
Firms that exported	575	171	29.7
All firms	723	204	28.2

For the firms that outsourced internationally (156), the survey also asked about their motives for doing so, and to which country or countries they outsourced. The survey suggested fourteen motives, and asked the firms to indicate whether each motive was considered to be very important, of some importance, not important, or not applicable/unknown. Table 5 shows for each motive the share of firms that considered it to be very important (column 1) or at least of some importance (column 2). Some of the motives suggested by the survey are overlapping. For example, costs reduction is also a way of improving or maintaining competitiveness. The most important motive for outsourcing internationally seems to be a reduction of labour costs. This is not surprising, since the wage level in the Netherlands is relatively high, and this means that large reductions in labour costs can potentially be made by employing employees in less developed countries. Other important motives are improving logistics, strategic decisions, and reducing other costs than labour costs. Many of the most important motives seem to focus on

cost reduction. This is consistent with the study by Van Gorp (2010), who finds that cost savings was most often mentioned as the most important objective.

Table 5. Most important motives for outsourcing (in percent)

Motive	Very important	Of some importance + very important
Reduction of labour costs	63	83
Improved logistics	49	76
Strategic decisions taken by the group head	44	69
Reduction of costs other than labour costs	24	66
Access to new markets	22	44
Focus on core business	21	43
Following the behaviour of competitors/clients	17	47
Improved/maintained competitiveness	15	34
Access to specialized knowledge/technologies	12	34
Improved quality or introduction of new products	10	29
Other motives	10	29
Tax or other financial incentives	5	28
Lack of available labour	4	19
Less regulation affecting the enterprise	2	3

The importance of the reducing labour costs suggests that most of the firms outsource their activities to less developed countries. The list of the most popular destination countries for outsourcing, which is shown in Table 6, confirms this. This table contains all destination countries that had a share of at least four percent for either outsourcing of core activities or outsourcing of support activities. The five most popular destination countries of outsourcing core activities are Poland (20 percent), China (19 percent), Czech Republic (19 percent), Germany (12 percent) and India (12 percent). Except for Germany, all of these countries have a considerably lower GDP per capita than the Netherlands (Penn World Table, Mark 7.1).

Table 6. Most popular destination countries for international outsourcing

Ranking (based on column 3)	Country	Outsourced core activities to this country (in percent)	Outsourced support activities to this country (in percent)
1	Poland	20	9
2	China	19	6
3	Czech Republic	19	12
4	Germany	12	18
5	India	12	18
6	Hungary	9	2
7	Slovakia	6	4
8	Belgium	4	13
9	Italy	4	3
10	Romania	4	3
11	Malaysia	4	3
12	France	2	13
13	United States	2	8
14	United Kingdom	1	13
15	Switzerland	< 1	4
16	Other Asia	13	8
17	Other EU-15	11	11
18	Other Americas	6	3
19	Africa	5	1
20	Other Eastern Europe	6	4

Note: the unrounded percentages add up to more than 100 percent (161 percent for core activities and 158 percent for support activities), because some firms outsourced to multiple countries.

It is also interesting to see that distance seems to be important. Relatively many firms outsource to countries in Eastern Europe, which have higher wages than countries like India and China, but are much closer to the Netherlands. Due to a combination of relatively low wages and a short distance to the Netherlands, Eastern Europe is the most popular destination for outsourcing of core activities, with a share of 40 percent of the core activities outsourced internationally.[3] Asia is the second most popular area, with a share of 30 percent. Germany (12 percent) and Belgium

[3] These shares are calculated by dividing by the number of combinations of firms and destination countries and therefore add up to 100 percent. The shares in Table 6 are divided by the number of firms that outsourced internationally and therefore add up to more than 100 percent.

(4 percent) are relatively popular as well, but the conceptual difference between domestic outsourcing within the Netherlands and outsourcing to a neighbouring country is not very large, especially if the firm is located close to the border. The country shares for outsourcing of support activities show significant differences from the country shares of outsourcing core activities. For support activities, the most popular destination countries are Germany (18 percent), India (18 percent), Belgium (13 percent), France (13 percent) and the United Kingdom (13 percent). Except for India, these countries are all adjacent or very close to the Netherlands. Of all the support activities that were outsourced internationally, 45 percent was outsourced to countries within the EU-15, which makes the EU-15 the most popular destination area for outsourcing support activities, followed by Asia (22 percent) and Eastern Europe (22 percent).[3]

2.2 Production data

The second data source is the production statistics database, which is also obtained from Statistics Netherlands (CBS). These data are used to determine productivity at the firm level. A firm can have multiple plants, but we do not have production data on individual plants. Therefore we only study the effects of outsourcing on the level of firms. The production statistics are based on several surveys, which are sector specific. We used the data covering the sectors mining, industry, construction, wholesale, retail, services, research and development, and transport. The survey does not follow all firms over time; rather it randomly selects a number of firms every year. However, the firms that have at least 100 employees are surveyed every year. Our data cover the period 1993 to 2008. The database contains the annual output and cost components according to the KLEMS framework. This includes total output (Q), capital costs (K), labour costs (L), energy costs (E), costs of materials (M) and costs of services (S). Table 7 shows how output and the cost components are defined.

Table 7. Output and input measures in the KLEMS framework

	Description small firms	Description large firms
Output (*Q*)	turnover main activity + turnover from trade and other activities -/- purchase value of trade goods + other income n.e.s.	turnover main activity + turnover from trade and other activities -/- purchase value of trade goods + other income n.e.s. + inventory changes + income from employees stationed elsewhere + received payments from insurance + activated costs of investments
Capital (*K*)	depreciation on fixed assets + interest on debt	depreciation on fixed assets + interest on debt
Labour (*L*)	total labour costs, including taxes	total labour costs, including taxes
Energy (*E*)	energy costs	energy costs
Materials (*M*)	purchase value of turnover -/- purchase value of trade goods	purchase value of used materials in production process + purchase value of other materials + outsourcing costs + purchase value n.e.s.
Services (*S*)	cost of transportation + housing costs + other personnel costs + sales costs + communication costs + costs of services from third parties + other costs	cost of transportation + housing costs + other personnel costs + sales costs + communication costs + costs of services from third parties + other costs -/- taxes on vehicles -/- environmental taxes -/- real estate taxes -/- other cost price increasing taxes

In some cases (for *Q*, *M* and *S*) the definition of the cost components differs between small and large firms. The purchase value of trade goods is not included on both the output side (*Q*) and input side (*M*). The output of a trading firm is therefore equal to the margin over the turnover. The measure of capital (*K*) only includes the depreciation on fixed assets and interest payments. This leads to some drawbacks. First, the value of fixed assets on the balance sheet is not always

the same as the economic value of these assets. Second, the measure of K is affected by the extent to which the firm is financed by debt or equity. K will be lower for a firm that is fully financed by equity, as it does not pay any interest. However, there is of course a shadow cost to using equity, which is not taken into account. The optimal measure of K would include the equity of the firm, multiplied by a firm-specific discount rate that depends on the risk level of the equity. However, due to considerations of data availability, we follow the definitions of the KLEMS framework.

We used the main economic activity of the firms to classify them into 26 sectors. Table B1 shows the SBI 1993 codes for this classification, as well as the number of observations that are available in the outsourcing survey and in the production data, for each sector. The average values of the key variables from the production data are provided for each year and for each sector in tables C1 and C2. Figures 4 and 5 show the development over time of the average cost shares of labour and intermediates ($E + M + S$). These are unweighted averages and are based on all firms that were available. It was not feasible to use a balanced panel of firms, because the number of firms that was available in all years of the period 1993–2008 was very low. Therefore, it is possible that the development of the cost shares is affected by the composition of firms that were available. Figures 4 and 5 show that, until the year 2000, the average cost shares of labour and intermediates were very similar between the group of firms that outsourced and the group of firms that did not outsource. From 2000 onwards, the outsourcing firms were characterized by a lower labour share and a higher share of intermediates, which is consistent with the definition of outsourcing. When a firm outsources part of its activities, it will buy the intermediates from a third party instead of producing them within the firm. This causes the share of intermediates in total inputs to increase. The firm will require less labour, which causes the share of labour in total inputs to decrease. Some labour will still have to be allocated to manage the outsourcing contracts.

Figure 4. Development of average share of labour in total inputs, 1993–2007

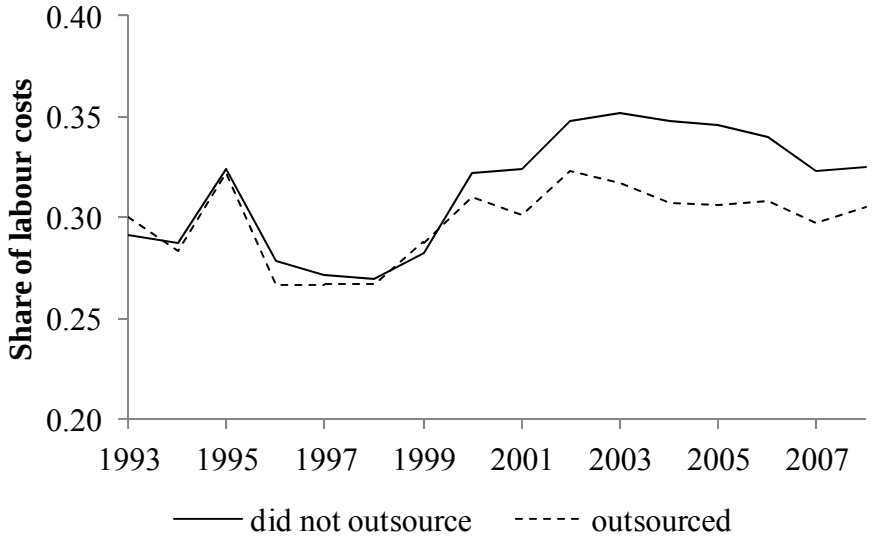
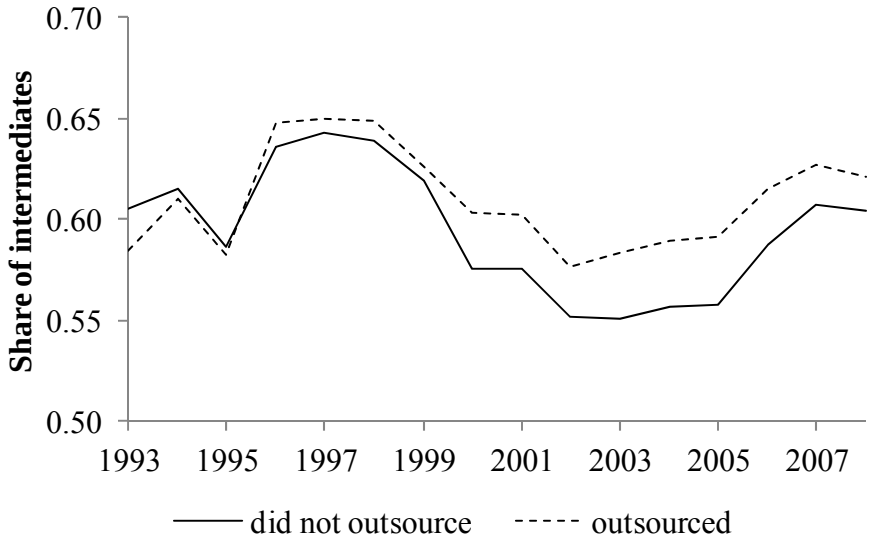


Figure 5. Development of average share of intermediates in total inputs, 1993–2007



From the perspective of the firm, outsourcing should either result in less total costs for the same quality of intermediates or in an increased quality of intermediates for the same amount of total costs. Since we cannot observe the quality of intermediates, this is an argument for using values instead of volumes, since the values of intermediates should capture the quality as well. From the perspective of the country, domestic outsourcing should lead to a more efficient allocation of jobs between firms within the country. In the case of international outsourcing, the employees

that were previously performing the outsourced tasks will become available for more productive tasks than they used to perform. It is likely that they can be used for more productive tasks, because the fact that the task was outsourced internationally is an indication that the country has a comparative disadvantage for that particular task.

3 Productivity measures

The previous section described our data source for firm inputs and output. We use these data to create two indicators for firm productivity: (i) labour productivity and (ii) total factor productivity (TFP). This section explains how these measures are constructed. It also contains density functions of the productivity measures. These density functions show that firms greatly vary in their productivity. This observation fits in the theoretical model of Melitz (2003), which assumes firms are heterogeneous in their productivity. In this model firms only enter the market if they are sufficiently productive, and only the most productive firms export to foreign markets. Therefore, firms that export are on average more productive than firms that do not export. The density functions shown in this section give an indication whether a similar result can be found for outsourcing. Section 4 will show the results of a more formal regression analysis about the possible relationship between outsourcing and productivity.

3.1 Labour productivity

We define labour productivity as the amount of output per unit of labour. Units of labour can be measured in different ways. For example, as the number of employees, the number of hours worked, or the amount of money spend on labour. We consider two measures for labour productivity, which are

output per full-time equivalent:

$$\lambda_{fte,i} = \frac{Q_i}{fte_i}, \tag{1}$$

and output per euro of labour costs (L):

$$\lambda_{L,i} = \frac{Q_i}{L_i}. \tag{2}$$

The number of full-time equivalents is calculated based on the number of days worked, since data on hours worked is unavailable for most employees.[4] This measure for labour productivity is only available for the period 2000–2008.

The second measure for labour productivity uses labour costs as the denominator. This measure is available for the full period 1993–2008. An advantage of using labour costs is that it takes into account that employees are heterogeneous. After all, a high-skilled worker will most likely generate more output than a low-skilled worker. If the labour market is efficient, labour costs should fully compensate for productivity differences of employees. Therefore, this measure for labour productivity is less dependent on the heterogeneity of employees in the firm, and more on the labour intensity of the production process, and on the skills of the management in selecting the right employees. Figures 6 and 7 show the development of the average labour productivity for three groups of firms: for firms that did not outsource any activities during the 2001–2006 period, for firms that did outsource, and for firms that outsourced internationally. Figure 6 contains labour productivity as measured by output divided by full-time equivalents, for the period 2000–2008. Figure 7 shows the development of the second measure for labour productivity, defined as output divided by labour costs, for the period 1993–2008.

As Figure 6 shows, the average output per full-time equivalent of the firms in the outsourcing survey is about 200,000 euro.[5] The average output somewhat decreases between 2000 and 2004 and increases after 2004, which may be related to the business cycle. The labour productivity is highest for firms that outsourced internationally and lowest for firms that did not outsource. This pattern is consistent over all years. The difference in labour productivity between these three groups of firms does not appear to change significantly over time. This indicates that firms with a higher labour productivity were more likely to outsource (internationally), but that the outsourcing did not have a large effect on their labour productivity.

[4] We realize that this will underestimate the measure for labour productivity for firms with relatively many part-time employees. However, if there is a strong sectoral component of the share of part-time employees we are able to correct for this by including sector dummies. Moreover, it only causes an underestimation if the part-time employees work only part of the day. If they work full days, but less than five days per week, this will not affect the labour productivity measure, since the number of days worked is correct.

[5] The average is based on the firms for which output was available from the KLEMS data. Since this data source is not a balanced panel, the selection of firms that are used to calculate the average varies over time.

Figure 7 shows a similar picture for the average output per unit of labour costs. The ranking of the three groups of firms is exactly the same in all years.

Figure 6. Average output per fte (in thousands of 2008 euros), 2000–2008

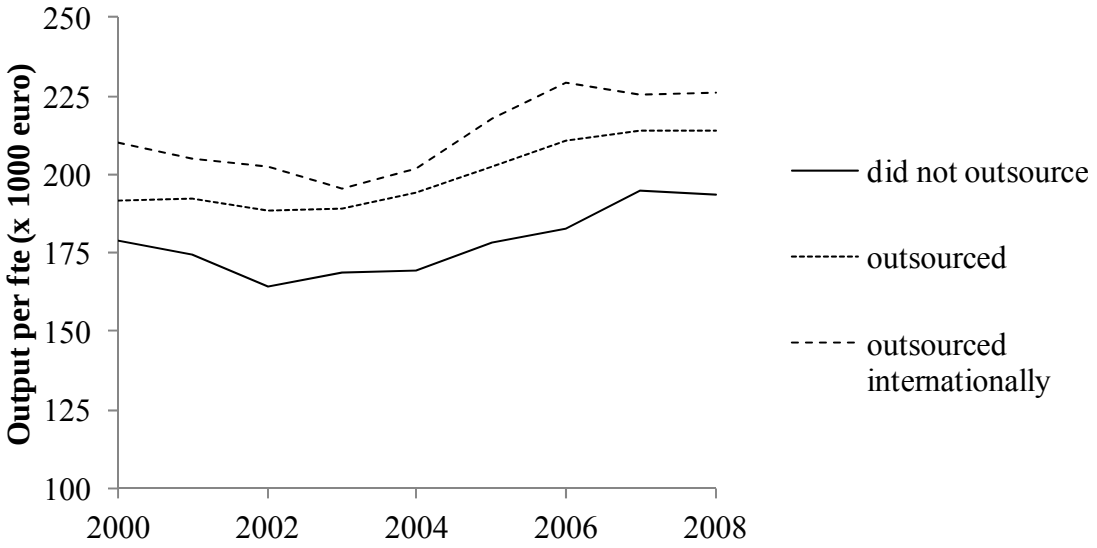


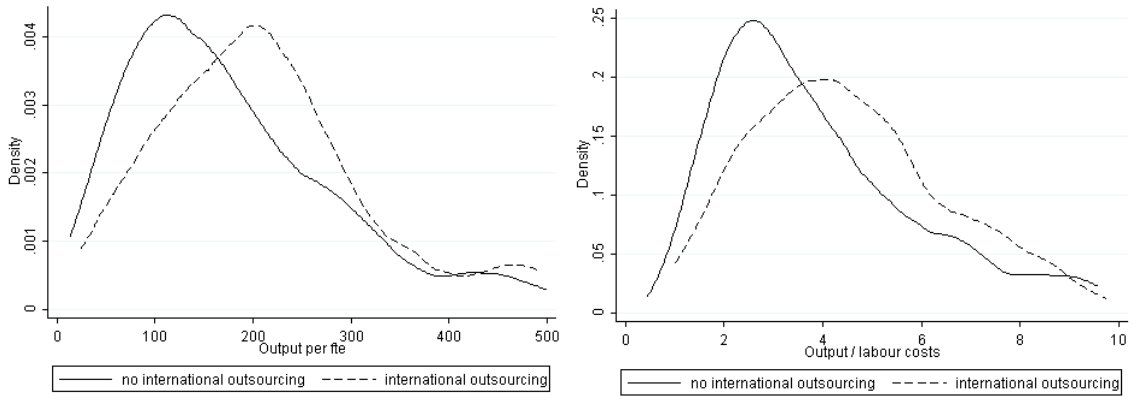
Figure 7. Average output per unit of labour costs, 1993–2008

To provide more insight into the differences of labour productivity across firms, we also show the density function of labour productivity. Figure 8 depicts the smoothed density functions for our two measures of labour productivity in 2000, for firms that did and for firms that did not

outsource internationally in the period 2001–2006. Labour productivity, measured as output per unit of labour costs, was capped at 10. The second graph, containing output per full-time equivalent, was capped at 500. The reason for this is to avoid outliers affecting the scale of the figures. Both figures cover about 90 percent of the firms. For both measures of labour productivity, the distribution of firms that outsourced internationally is more to the right, compared to firms that did not outsource internationally. The density of firms with a relatively low labour productivity is higher for firms that did not outsource internationally, while the density of firms with a relatively high labour productivity is higher for firms that did outsource internationally.

Figure 8. Smoothed density function for labour productivity, 2000

A. Output per fte (in thousands 2008 euros) *B. Output per unit of labour costs*

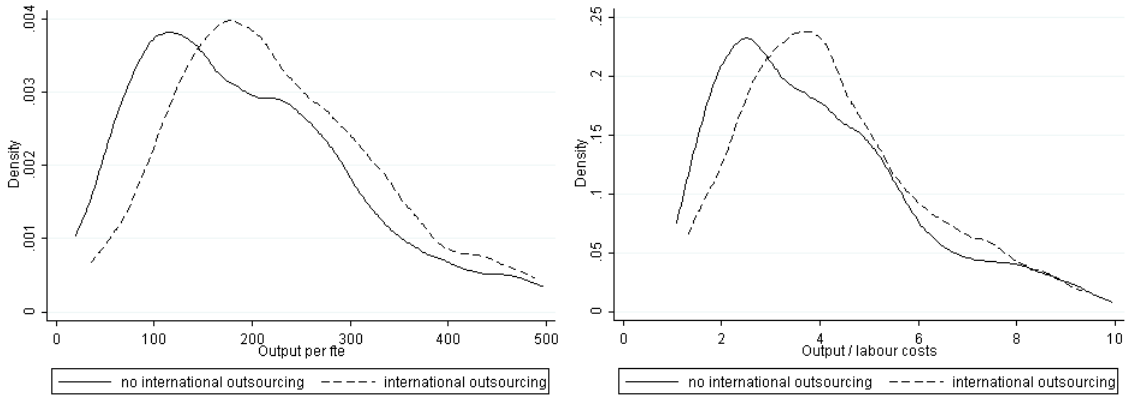


Since the survey question covered the period 2001–2006, this means that firms that outsourced internationally in that period already had a higher labour productivity before they started outsourcing. This suggests a selection effect, meaning that firms with a higher labour productivity are more likely to outsource internationally. This applies to both measures for labour productivity, indicating that these firms had a higher output per full-time equivalent as well as a higher output per unit of labour costs. Note that it is possible that this is caused by other firm characteristics, like the economic activity of the firm. Section 4 contains results of regression analyses that adjust for these.

Figure 9 contains the same graphs as Figure 8, but now for the year 2008 instead of 2000. These graphs show a similar picture as for the year 2000. This indicates that the firms that outsourced also had a higher labour productivity during and after the outsourcing was initiated. The difference between firms that did outsource internationally and firms that did not outsource does not appear to be significantly different across time.

Figure 9. Smoothed density function for labour productivity, 2008

A. Output per fte (in thousands 2008 euros) B. Output per unit of labour costs



3.2 Total factor productivity

An alternative indicator for firm performance is total factor productivity (TFP), which takes into account the contribution of other inputs to output as well. TFP is defined as the firm-specific residual of an estimated production function. We estimate TFP by estimating production functions for several sectors, using all firms in the Netherlands for which the KLEMS data are available.

Recently, there has been a renewed interest in the estimation of production functions as a result of an increase in the availability of plant-level data that allows for plant level productivity estimations (see, e.g., Syverson, 2011; Bartelsman and Doms, 2000). This renewed interest has also led to more advanced estimation methods than the traditional OLS estimations. An important drawback of the traditional estimation method is that productivity is likely to be correlated with the level of inputs, since the firm is able to observe its own productivity. This

will cause OLS estimates to be biased. This problem was already recognized in Marschak and Andrews (1944). In the literature, it is usually referred to as the simultaneity problem (see Griliches and Mairesse, 1998, for an extensive overview).

Solutions to this problem have been presented by Olley and Pakes (1996) and by Levinsohn and Petrin (2003). Olley and Pakes (1996) use the investment decision of the firm as a proxy for unobserved productivity shocks. As this method requires data on annual investments, which are not available to us, we follow the solution described by Levinsohn and Petrin (2003). Their solution is similar to that of Olley and Pakes (1996), but uses intermediate inputs, instead of investments, as a proxy for unobserved productivity shocks. In our dataset, intermediate inputs are available from the KLEMS framework. We take the sum of energy costs (E), costs of materials (M) and costs of services (S) as the proxy variable. Appendix D gives a technical overview of the Levinsohn and Petrin (2003) approach for the case where value added is estimated as a function of capital and labour.

A second potential problem with estimating production functions is the selection bias (Wedervang, 1965). This selection bias results from the relationship between productivity and the exit probability. This problem is most prominent when using a balanced panel (Van Beveren, 2012). Our analysis is based on an unbalanced panel, since there is only a small number of firms that were present in all 16 years. We refer to Appendix C for a general overview of the sample that was used for estimating the production functions. Table C3 shows the number of occurrences of firms in the sample. Even in an unbalanced panel, the selection bias may still be present, due to a potential negative correlation between the amount of capital and the exit decision of a firm. When a firm expects to exit, it is likely to decrease its capital stock in advance. This may cause a downward bias in the capital coefficient. Olley and Pakes (1996) propose to first estimate survivability as a function of capital and investment. Due to a lack of good data on investments, we were not able to follow this approach.

We used the Stata syntax from Petrin et al. (2003) to estimate production functions for each of the 26 sectors which are defined in Table B1. Estimating a separate production function for each sector allows for heterogeneity between sectors in the production technology. We explain value added (VA) as a function of capital costs (K) and labour costs (L), and use intermediates as a proxy for unobserved productivity shocks. We choose to use value added as the dependent variable, rather than total output, because outsourcing affects the share of

intermediates in total output. This would bias the results, since our estimates of TFP are based on the assumption of a homogeneous production function within sectors. If the input mix of a firm deviates from the optimal mix of the sector, as estimated by the production function, while still having the same output, it would get a positive error term. The reason for this is that a firm is considered to be more productive if it can obtain the same output with a suboptimal input mix. However, it is possible that the production technology is heterogeneous within sectors as well. The implication of this is that the change in TFP of firms which are moving away from the average input mix is being overestimated, and vice-versa for firms moving towards the average input mix. Firms that outsource are expected to move away from the average input mix since they substitute labour and capital for intermediates.

In the KLEMS framework, all inputs are measured in cost units. This means, that the total wage bill is considered, rather than the number of hours worked. The advantage of this way of measuring inputs is that there is less reason for concern about quality differences of the output and of the inputs. We assume that market prices adequately pick up these quality differences. For example, a firm with high-skilled employees will generally produce more output with the same number of hours worked and will therefore have a higher TFP when this is estimated using the number of hours worked. This problem is avoided if wages reflect individual productivity differences. By using the total wage bill instead, we avoid finding a spurious result caused by a possible relationship between the skill level of the employees and our measure for diversity. A disadvantage of using cost units rather than volumes is that price changes can affect TFP. For example, when input prices increase more than output prices, our estimates for TFP will decrease, even when the volumes remain unchanged. However, since we estimate production functions by sector, this is less problematic since output and input prices at the firm level often correlate within a sector. Our measure for TFP should be interpreted as an indicator for productivity relative to other firms in the same sector. Moreover, price changes are not necessarily exogenous, as the firm itself may negotiate better input prices or improve output prices, for example by a successful advertising campaign. In such cases, cost units are to be preferred over volumes. To avoid that general inflation affects the results, we deflated all output and input values by the CPI from Statistics Netherlands.

We estimate a Cobb-Douglas production function, where value added (VA) is a function of some combination of the inputs capital (K) and labour (L):

$$VA_{it} = A_{it} K_{it}^{\beta_K} L_{it}^{\beta_L}, \tag{3}$$

with A_{it} representing the TFP of firm i in year t.

Within the KLEMS framework, value added is defined as output (Q) minus inputs (E, M, S). Although less restrictive functional forms, like a transcendental logarithmic function, can be used, in practice the chosen functional form does not matter much numerically (Arnold, 2005). Moreover, we choose to follow the estimation method by Levinsohn and Petrin (2003), which is only programmed for the Cobb-Douglas function (Petrin et al., 2003).

For all sectors, the sum of the estimated coefficients for capital and labour is lower than one, indicating decreasing returns to scale. After estimating the sector-specific production functions, the procedure by Levinsohn and Petrin (2003) calculates the predicted value added, based on capital and labour inputs. The difference between the natural logarithm of the actual value added and the natural logarithm of the predicted value added represents the natural logarithm of A_i from equation (3), which we will refer to as the TFP of the firm in the rest of this paper. We adjusted the TFP by subtracting the average TFP of the sector in each year, so that the average TFP is zero for each sector in each year.

Figure 10 shows the development of the average TFP for firms that were in the outsourcing survey. It shows that the average TFP deviates relatively much from zero. As explained in the previous paragraph, the average TFP for each sector in each year is set to zero for the entire population of Dutch firms for which we could estimate TFP. It turns out that the firms in the outsourcing survey were on average more productive compared to other firms in their sector. This is not surprising, as the survey was targeted at large firms, which are found to be more productive than smaller firms. The pattern of the average TFP deviation may be related to the business cycle. According to the Dutch national accounts, the Netherlands experienced relatively high GDP growth rates between 1994 and 2000. It is possible that large firms, which are overrepresented in this sample, benefit more from a boom than smaller firms. Additionally, we find that firms that outsourced in the period 2001–2006 were more productive in all years compared to firms that did not outsource any activities. This means that firms that outsourced

perform consistently better, even after adjusting for sectoral effects and for capital and intermediate inputs.

Figure 10. Average TFP as deviation from the sector average, 1993–2008

Again, we also provide the distribution of TFP. Figure 11 shows the distributions of TFP in 2000, for firms that outsourced internationally and firms that did not do so. Figure 12 does the same for the year 2008. Both figures indicate that the TFP of firms that outsourced internationally is positioned more to the right compared to firms that did not outsource internationally. A similar result was found for labour productivity. Just like for labour productivity, the firms that outsourced internationally have a higher TFP in 2000 as well as in 2008, which indicates that the difference is mainly caused by a selection effect. This is also consistent with Figure 10, which shows the development of the average TFP between 1993 and 2008.

Figure 11. Density functions for total factor productivity, 2000

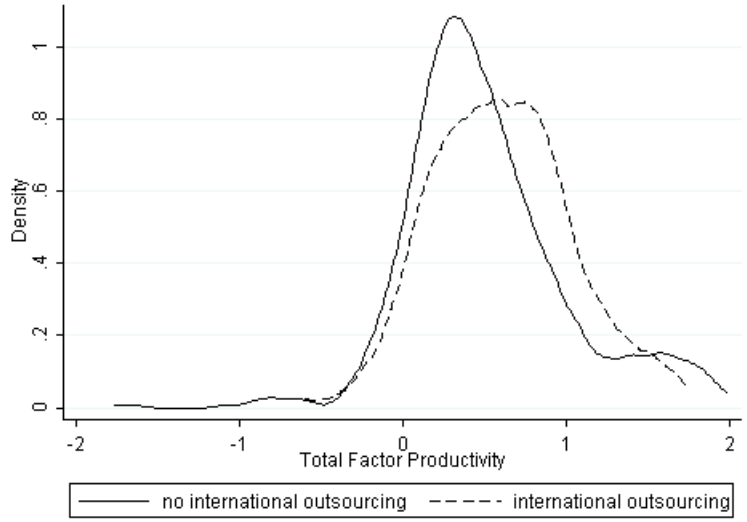
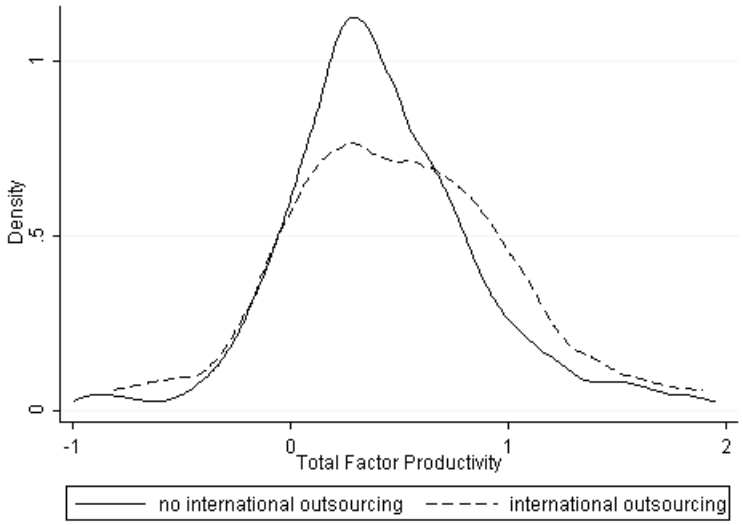


Figure 12. Density functions for total factor productivity, 2008



4 Estimation results

The previous section explained how we constructed our measures for firm productivity. It also provided some graphical indications for the existence of productivity differences between firms that did or did not outsource. This section presents the estimation results to determine the relationship between outsourcing and productivity, both for the level of productivity as well as for the growth of productivity. This is done for two of the indicators for productivity, which are

output per unit of labour costs and total factor productivity (TFP). The third indicator for productivity, output per full-time equivalent, is not included in this analysis, since it was only available from 2000 onwards, which makes it unsuitable to make a comparison before and after the outsourcing period.

The relationship between outsourcing and output per unit of labour costs was estimated by regressing labour productivity on the four indicators for outsourcing, and sector and year dummies:

$$\lambda_{L,it} = \alpha_s + y_t + \sum_{d=1}^{4} \beta_d out_{d,it} + \varepsilon_{it}, \tag{4}$$

where α_s is a sector-specific constant and y_t is a year-specific constant. The sector and year dummies account for differences in productivity between sectors and for business cycle effects, respectively. The model was estimated on firms with an output to labour costs ratio smaller than ten, to prevent outliers from influencing the results. This is particularly relevant for our measure for labour productivity, since it is a ratio, which can be extremely large if the denominator is very small. For the TFP measure this problem is less severe, since it is not calculated as a ratio. In the TFP regression we included all firms with a TFP between –2 and +2. Since TFP is measured as a logarithm, this means we included all firms that were between 13.5 percent and 739 percent as productive as the average of their sector. Almost all firms are within this range. For the regression for TFP, the sector and year dummies are not required, since our measure for TFP is already demeaned for each sector and year combination:

$$TFP_{it} = \sum_{d=1}^{4} \beta_d out_{d,it} + \varepsilon_{it}. \tag{5}$$

4.1 Labour productivity

Table 8 shows the estimation results for labour productivity, measured as the natural logarithm of the ratio between output and labour costs. The estimations are done for the period 1993–2000 and for the period 2001–2008. The reason for making this distinction is that the outsourcing indicators are based on the period 2001–2006. A relationship between productivity and outsourcing in the first period would suggest a selection effect. However, it is also possible that firms that outsourced in the period 2001–2006 had also outsourced before this period. Therefore,

this does not necessarily mean that such a relationship is purely due to a selection effect. Second, comparing the results for both periods could indicate an effect of outsourcing on the change of productivity. This issue will also be addressed later in this section, when we estimate a fixed effects model. In all pooled OLS regressions that contain multiple years, we adjusted the standard error for cluster-correlated data, since the same firms can be present in the data for multiple years, and their characteristics are likely to be correlated over time. A pooled OLS estimation without this correction would underestimate the standard errors (see, e.g., Cameron and Trivedi, 2005). The correction for cluster-correlated data is explained in Williams (2000) and the Stata syntax we used for this is explained in Rogers (1993).

The estimation results that are shown in Table 8 include four outsourcing indicators, which are all dummy variables. A firm can have a dummy of one for multiple types of outsourcing. The reference group consists of the firms that did not outsource any activities in the period 2001–2006. In all estimations in Table 8, we controlled for sector and year effects, which are not reported. A constant is also included, but not reported, since it depends on the omitted sector and year dummy. Column 1 and column 3 in Table 8 are estimated using observations from the period 1993–2000, which is the period before the period where the outsourcing survey focused on (2001–2006). Column 2 and column 4 are estimated on the period 2001–2008. This period also includes two years after the survey period. The reason for this is that firms that outsource may initially experience some adjustment costs in the short run. By including the years 2007 and 2008 we ensure that we also capture the effects of outsourcing on the medium run.

The first two columns of the table only distinguish between international and domestic outsourcing. The results show a positive relationship between international outsourcing and labour productivity, which is only statistically significant in the first period. This positive relationship is consistent with figures 8B and 9B, which showed that the distribution of firms that outsourced internationally was shifted to the right. This suggests that firms that outsourced internationally produced more output per unit of labour costs, at least before 2001, which implies a selection effect.

Columns 3 and 4 also distinguish between international and domestic outsourcing, which increases the number of outsourcing indicators from two to four. For these four outsourcing indicators, only the variable international outsourcing of core activities was statistically significant (positive in both periods). Since the positive relationship already existed before 2001,

and did not increase in the period after 2001, it suggests that firms with a higher labour productivity were more likely to outsource core activities internationally, and that this type of outsourcing had no strong effect on the level of labour productivity.

Table 8. Output labour cost ratio explained by outsourcing types (1993–2000 and 2001–2008)

	Dependent: ln(Output / labour costs)			
International outsourcing	0.08**	0.05		
	(0.04)	(0.03)		
Domestic outsourcing	–0.01	0.01		
	(0.05)	(0.05)		
International outsourcing of core activities			0.12***	0.08**
			(0.05)	(0.04)
Domestic outsourcing of core activities			–0.09	–0.02
			(0.07)	(0.05)
International outsourcing of support activities			–0.00	0.03
			(0.05)	(0.04)
Domestic outsourcing of support activities			–0.01	0.01
			(0.06)	(0.04)
Sector dummies	22	22	22	22
Year dummies	8	8	8	8
Period	1993–2000	2001–2008	1993–2000	2001–2008
Observations	2660	5150	2660	5150
Firm clusters	574	849	574	849
R^2	0.37	0.40	0.35	0.40

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). Constant not reported when sector and year dummies are included.

The results in Table 8 are based on estimations that did not correct for firm size. When we control for firm size, the results change somewhat, since firm size is correlated with outsourcing as well as with labour productivity. The positive correlation between firm size and labour productivity can, for example, be related to a higher capital intensity of large firms or stronger specialization of employees. In Table 9, we control for firm size, measured as the natural logarithm of output. The estimation results confirm that there is indeed a strong positive correlation between labour productivity and firm size. An increase of output by one percent is associated with an increase in labour productivity, measured as the ratio between output and labour costs, of 0.15 percent. When we control for firm size, the estimated coefficients for the

outsourcing indicators generally decrease. The coefficients for international and domestic outsourcing become statistically insignificant. Therefore we show the results for outsourcing of core activities and support activities instead, in the first two columns of Table 9.

Table 9. Output labour cost ratio explained by outsourcing types, controlling for firm size (1993–2000 and 2001–2008)

	Dependent: ln(Output / labour costs)			
Ln(firm output)	0.15***	0.15***	0.15***	0.15***
	(0.02)	(0.01)	(0.02)	(0.01)
Outsourcing of core activities	0.04	0.06*		
	(0.04)	(0.03)		
Outsourcing of support activities	–0.07*	– 0.06**		
	(0.04)	(0.03)		
International outsourcing of core activities			0.08*	0.06*
			(0.04)	(0.04)
Domestic outsourcing of core activities			–0.13**	–0.03
			(0.05)	(0.05)
International outsourcing of support activities			–0.06	–0.03
			(0.05)	(0.04)
Domestic outsourcing of support activities			–0.03	–0.04
			(0.05)	(0.04)
Sector dummies	22	22	22	22
Year dummies	8	8	8	8
Period	1993–2000	2001–2008	1993–2000	2001–2008
Observations	2660	5150	2660	5150
Firm clusters	574	849	574	849
R^2	0.46	0.48	0.46	0.48

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). Constant not reported when sector and year dummies are included.

For firms that outsourced their support activities, the ratio between output and labour costs was about seven percent lower in the period 1993–2000 and six percent lower in the period 2001–2008. For firms that outsourced their core activities, the relationship was statistically insignificant in the first period and just barely statistically significant and positive in the second period. Columns 3 and 4 distinguish between all four types of outsourcing. For these four outsourcing indicators, the only coefficients that are statistically significant are outsourcing of

international core activities (positive in both periods) and outsourcing of domestic core activities (negative in the first period). These results suggest that firms of similar size with a higher labour productivity were slightly more likely to outsource core activities internationally, and that this type of outsourcing had no effect on the level of labour productivity. Additionally, firms of similar size that outsourced core activities domestically had a slightly lower labour productivity in the period 1993–2000, but this difference disappeared in the period 2000–2008, suggesting a small positive effect of this type of outsourcing on labour productivity. This will be further tested using a fixed effects model.

The advantage of the fixed effects model is that all time-invariant characteristics of the firms are filtered out. However, an important limitation of our data is that we do not know exactly when the outsourcing took place. In a fixed effects model, the timing is important since it uses variation within the firm over time for identification. One way to create some variation over time within firms is by setting the outsourcing variables to zero before the year 2001 and to one in the years 2001 and onwards for firms that outsourced. For firms that did not outsource in the survey period, the variables remain zero for all years. In this way, the estimations from the fixed effects model will be based on a comparison of the change of productivity over time of firms that changed their outsourcing status with the change of productivity over time of firms that did not change their outsourcing status. This method assumes that all firms that outsourced in the survey period, started outsourcing at the start of the period and continued these contracts for the rest of the period. This is unlikely to be true, but it is not possible to determine when exactly they started outsourcing. An alternative assumption is that the expected probability of outsourcing increased over the survey period. This means that the probability of outsourcing was zero for all firms in all years before the outsourcing survey. For firms that answered that they outsourced somewhere in the period 2001–2006, we gradually increase the outsourcing indicator by 1/6 each year. So in 2001 the indicator will be 1/6, in 2002 it will be 2/6, increasing to one in 2006, 2007, and 2008.

Table 10 shows the estimation results for the fixed effects model, using both types of time variation. Both models include year dummies to control for the business cycle. This is particularly important, because the outsourcing indicators are, by definition, positively correlated across time. The results from the fixed effects model are mostly consistent with the change in the coefficients between the two periods in the cross-sectional estimations: firms that internationally (domestically) outsourced core activities decreased (increased) their labour productivity compared to firms that did not do so. For the other two types of outsourcing, no statistically significant relationship was found. The two models show comparable results, although the standard deviations are smaller for the second model.

Table 10. Output labour cost ratio explained by outsourcing types, fixed effects model

	Dependent: ln(Output / labour costs)	
Method of changing outsource variables	Sudden (2001)	Gradually (2001–2006)
International outsourcing of core activities	–0.09	–0.05**
	(0.07)	(0.02)
Domestic outsourcing of core activities	0.12***	0.11***
	(0.05)	(0.05)
International outsourcing of support activities	–0.01	0.03
	(0.06)	(0.02)
Domestic outsourcing of support activities	–0.00	–0.03
	(0.05)	(0.02)
Period	1993–2008	1993–2008
Year dummies	16	16
Observations	7810	7810
Number of groups	853	853
Smallest group	1	1
Average group	9.2	9.2
Largest group	16	16
Within R^2	0.052	0.052

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). Constant not reported when sector and year dummies are included.

4.2 Total factor productivity

Although labour productivity is an interesting characteristic of a firm, a better measure for its productivity is total factor productivity (TFP), since it also corrects for capital and intermediate inputs. Table 11 provides the estimation results for TFP, for the period 1993–2000 and for the period 2001–2008. Sector and year dummies are not included, since the measure for TFP has been estimated on a sectoral level and is demeaned for each sector and year combination. This means that the average TFP of all firms in a particular sector in a particular year is always zero. However, these regressions only include firms that participated in the outsourcing survey, which is the reason why the constant is not zero. In fact, the constant is rather high, which implies that the outsourcing survey is biased to more productive firms. This is not very surprising, as it was targeted at large firms, which are found to have a higher average TFP than small firms.

The first two columns show that domestic and international outsourcing have positive coefficients in both periods. The positive coefficient for international outsourcing confirms the results suggested by figures 11 and 12. However, it is only barely statistically significant in the period 1993–2000, and not statistically significant in the period 2000–2008. If we split these measures up according to core and support activities, the positive relationship between firms that outsourced internationally and TFP seems to come from firms that internationally outsourced support activities, and not from firms that internationally outsourced core activities. The coefficient for international outsourcing of core activities is negative and statistically significant at a ten percent significance level in the period 2001–2008. Since the relationship between international outsourcing of support activities and TFP was already positive in the period before the survey period, this indicates a selection effect, rather than a causal effect of outsourcing on TFP. For firms that internationally outsourced core activities the coefficient decreased over time, and for firms that domestically outsourced support activities the coefficient increased over time.

Table 11. Total factor productivity explained by outsourcing types (1993–2000 and 2001–2008)

	Dependent: TFP			
International outsourcing	0.08*	0.03		
	(0.04)	(0.04)		
Domestic outsourcing	0.01	0.06		
	(0.06)	(0.04)		
International outsourcing of core activities			–0.02	–0.08*
			(0.05)	(0.05)
Domestic outsourcing of core activities			0.00	–0.03
			(0.11)	(0.08)
International outsourcing of support activities			0.17***	0.15***
			(0.06)	(0.05)
Domestic outsourcing of support activities			0.02	0.08*
			(0.06)	(0.05)
Constant	0.47***	0.45***	0.47***	0.45***
	(0.02)	(0.02)	(0.02)	(0.02)
Period	1993–2000	2001–2008	1993–2000	2001–2008
Observations	2791	5491	2791	5491
Firm clusters	598	877	598	877
R^2	0.005	0.003	0.010	0.013

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). Sector and year dummies are not included, since the measure for TFP is already demeaned for each sector and year combination. TFP is defined as the difference between the natural logarithm of the actual output and the natural logarithm of the predicted output.

An alternative specification of the model also controls for the size of the firm. Table 12 shows that there is a strong relationship between firm size, measured as the natural logarithm of total output, and TFP. An increase of the firm size of one percent is associated with an increase of TFP of 0.22 percent. Table 9 showed that a similar positive relationship also exists between firm size and labour productivity. After adjusting for firm size, the outsourcing coefficients generally decrease. This is caused by the positive correlation between outsourcing and firm size on the one hand, and between TFP and firm size on the other hand.

Table 12. Total factor productivity explained by outsourcing types, controlling for firm size (1993–2000 and 2001–2008)

	Dependent: TFP			
Ln(output)	0.22***	0.22***	0.22***	0.22***
	(0.02)	(0.01)	(0.02)	(0.01)
Outsourcing of core activities	–0.08**	–0.11***		
	(0.04)	(0.04)		
Outsourcing of support activities	0.06	0.04		
	(0.04)	(0.03)		
International outsourcing of core activities			–0.08*	–0.12***
			(0.04)	(0.04)
Domestic outsourcing of core activities			–0.08	–0.12*
			(0.09)	(0.07)
International outsourcing of support activities			0.08*	0.05
			(0.04)	(0.04)
Domestic outsourcing of support activities			0.02	0.03
			(0.05)	(0.04)
Constant	–1.82***	–1.83***	–1.81***	–1.81***
	(0.16)	(0.10)	(0.10)	(0.10)
Period	1993–2000	2001–2008	1993–2000	2001–2008
Observations	2791	5491	2791	5491
Firm clusters	598	877	598	877
R^2	0.24	0.29	0.24	0.29

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). Sector and year dummies are not included, since the measure for TFP is already demeaned for each sector and year combination. TFP is defined as the difference between the natural logarithm of the actual output and the natural logarithm of the predicted output.

It is difficult to determine how the causality runs between outsourcing, TFP and size. For example, firms could be larger because they are more productive, or they could be more productive because they are larger. However, it does seem to be the case that firms that outsourced core activities had a lower TFP than firms with a similar size that did not outsource their core activities. Firms that outsourced support activities had a somewhat higher TFP compared to firms with a similar size that did not outsource any support activities, although this difference is not statistically significant at a ten percent significance level.

Table 13. Total factor productivity explained by outsourcing types, fixed effects estimations

	Dependent: TFP					
Method of changing outsource variables	Sudden (2001)	Sudden (2001)	Sudden (2001)	Gradually (2001–2006)	Gradually (2001–2006)	Gradually (2001–2006)
Outsourcing of core activities	–0.10***			–0.13***		
	(0.02)			(0.02)		
Outsourcing of support activities	0.05***			0.07***		
	(0.02)			(0.02)		
International outsourcing		–0.07***			–0.10***	
		(0.02)			(0.02)	
Domestic outsourcing		0.05**			0.04**	
		(0.02)			(0.02)	
International outsourcing of core activities			–0.11***			–0.14***
			(0.02)			(0.03)
Domestic outsourcing of core activities			–0.08**			–0.05*
			(0.04)			(0.03)
International outsourcing of support activities			0.02			0.03
			(0.03)			(0.03)
Domestic outsourcing of support activities			0.08***			0.11***
			(0.03)			(0.03)
Constant	0.48***	0.48***	0.48***	0.48***	0.48***	0.48***
	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)	(0.004)
Observations	8282	8282	8282	8282	8282	8282
Fixed effects groups	880	880	880	880	880	880
Min *N*	1	1	1	1	1	1
Average *N*	9.4	9.4	9.4	9.4	9.4	9.4
Max *N*	16	16	16	16	16	16
Within R^2	0.004	0.002	0.005	0.010	0.009	0.012

Notes: standard errors (corrected for cluster-correlation) are shown in parentheses. Statistical significance levels are indicated by *** (1%), ** (5%) and * (10%). TFP is defined as the difference between the natural logarithm of the actual output and the natural logarithm of the predicted output.

To further explore a possible causal relationship between the types of outsourcing and TFP, we use the fixed effects models that were discussed in the section on labour productivity (Section 4.1). The results presented in Table 13 are consistent with those of the OLS estimations in Table 11: firms that outsourced core activities decreased their TFP compared to firms that did not. And firms that domestically outsourced support activities increased their TFP compared to firms that did not. International outsourcing of support activities had no statistically significant effect.

5 Conclusions

This study investigated whether firms that outsourced are more productive than firms that did not outsource, and whether there exists a selection effect. To answer these questions we looked at three different measures for productivity: labour productivity measured as the ratio between output and labour costs, labour productivity measured as output per fte, and total factor productivity (TFP).

The first conclusion is that larger firms are more productive than smaller firms. An increase of the firm size of one percent is associated with an increase of TFP of 0.22 percent. The evidence on outsourcing is rather mixed and depends strongly on the type of outsourcing. The strongest relationship was found for firms that internationally outsourced support activities. These firms were statistically significantly more productive than firms that did not outsource any support activities internationally. Since the relationship already existed before the outsourcing survey period, this implies that more productive firms self-select themselves into this type of outsourcing. This is similar to the positive selection effect that is found for firms in the Netherlands (Kox and Rojas-Romagosa, 2010). However, for the other types of outsourcing we did not find any selection effect. It is possible that self-selection effects are more likely to occur for exporting than for outsourcing, because exporting is a sign of being more productive than other firms, while outsourcing is a sign of being less productive than another firm. For exporting, a selection effect is likely to occur, because exporting requires some fixed cost that only the most productive firms are able to afford. Since similar fixed costs are present for (international) outsourcing, one could expect a selection effect to occur with outsourcing as well. However, firms only outsource when a third party can produce some part of the production process more efficiently than they can themselves. This becomes more likely when the firm itself is less productive. This would suggest that less productive firms are more likely to outsource. This effect might cancel out the effect predicted by the existence of fixed costs, and could explain that such a selection effect is less prominent for outsourcing.

Regarding the effect of outsourcing on the change in productivity, we found that firms that outsourced core activities decreased their TFP compared to firms that did not. And firms that domestically outsourced support activities increased their TFP compared to firms that did not. Domestic outsourcing of core activities had a barely significant negative effect on TFP, and international outsourcing of support activities had an insignificant positive effect. Obviously,

firms will not decide to outsource if they expect a negative return. However, the fixed effects model predicts a negative return on international outsourcing of core activities. This could be caused by measurement or econometric problems, but it could also imply that international outsourcing of core activities was less successful than the firms thought it would be. It is possible that this is caused by higher than expected inter-firm transaction costs. In the survey by Van Gorp (2010), the most often mentioned reasons for firms not achieving their objectives are governance, higher than expected costs, more time needed, lack of market potential, and cultural differences. Van Gorp (2010) mentions that about 17 percent of the internationally outsourced activities were relocated back to the Netherlands. The inter-firm transaction costs may be higher in the case of international outsourcing than in the case of domestic outsourcing, for example, in the case of cultural differences (see Möhlmann et al. (2010) for a discussion on cultural differences and international trade). Additionally, if something goes wrong at the insourcing firm, it might be more costly for the outsourcing firm in the case of core activities than in the case of support activities. These reasons might explain the result that firms that domestically outsourced support activities did increase their productivity while firms that outsourced core activities decreased their productivity.

References

Abraham, K.G. and S. Taylor (1996): 'Firms' Use of Outside Contractors: Theory and Evidence', *Journal of Labor Economics*, 14, pp. 394–424.

Amity, M. and S. Wei (2004): *Services Outsourcing, Production and Employment: Evidence from the US*, CEPR Discussion Paper, no. 5475, London.

Antràs, P. and E. Helpman (2004): 'Global Sourcing', *Journal of Political Economy*, 112, pp. 552–580.

Arnold, J.M. (2005): *Productivity Estimation at the Plant Level: A Practical Guide*, Working Paper, Bocconi University.

Balassa, B. (1967): *Trade Liberalization among Industrial Countries*, McGraw-Hill, New York.

Bartelsman, E.J. and M. Doms (2000): 'Understanding Productivity: Lessons from Longitudinal Microdata', *Journal of Economic Literature*, 38, pp. 569–594.

Bernard, A.B., J.B. Jensen, S.J. Redding and P.K. Schott (2007): 'Firms in International Trade', *Journal of Economic Perspectives*, 21, pp. 105–130.

Van Beveren, I. (2012): 'Total Factor Productivity Estimation: a Practical Review', *Journal of Economic Surveys*, 26, pp. 98–128.

Cameron, A.C. and P.K. Trivedi (2005): *Microeconometrics: Methods and Applications*, Cambridge University Press, Cambridge.

Den Butter, F.A.G., J.L. Möhlmann and P. Wit (2008): 'Trade and Product Innovations as Sources for Productivity Increases: an Empirical Analysis', *Journal of Productivity Analysis*, 30, pp. 201–211.

Egger, H. and P. Egger (2006): 'International Outsourcing and the Productivity of Low-skilled Labour in the EU', *Economic Inquiry*, 44, pp. 98–108.

Findlay, R. (1978): 'An Australian Model of International Trade and Interest Rate Equalization', *Journal of Political Economy*, 86, pp. 989–1008.

Geishecker, I., H. Görg and S. Maioli (2008): 'The Labour Market Impact of International Outsourcing', in: D. Greenaway and P. Wright (eds.), *Globalisation and Labour Market Adjustment*, Palgrave Macmillan, Basingstoke, Hampshire.

Girma, S. and H. Görg (2004): 'Outsourcing, Foreign Ownership, and Productivity: Evidence from UK Establishment-Level Data', *Review of International Economics*, 12, pp. 817–832.

Görg, H. and A. Hanley (2005): 'International Outsourcing and Productivity: Evidence from the Irish Electronics Industry', *North American Journal of Economics and Finance*, 16, pp. 255–269.

Görg, H., D. Greenaway and R. Kneller (2008): *The Economic Impact of Offshoring*, Report for Norwich Union, London.

Griliches, Z. and J. Mairesse (1998): 'Production Functions: The Search for Identification', in: S. Ström (ed.), *Econometrics and Economic Theory in the 20th Century: The Ragnar Frisch Centennial Symposium*, Cambridge University Press, Cambridge.

Grossman, G.M. and E. Rossi-Hansberg (2008): 'Trading Tasks: A Simple Theory of Offshoring', *American Economic Review*, 98, pp. 1978–1997.

Kox, H.L.M. and H. Rojas-Romagosa (2010): 'Exports and Productivity Selection Effects for Dutch Firms', *De Economist*, 158, pp. 295–322.

Krugman, P.R. (1995): 'Growing World Trade: Causes and Consequences', *Brookings Papers on Economic Activity*, 1, pp. 327–377.

Levinsohn, J. and A. Petrin (2003): 'Estimating Production Functions using Inputs to Control for Unobservables', *Review of Economic Studies*, 70, pp. 317–341.

Marschak, J. and W. Andrews (1944): 'Random Simultaneous Equations and the Theory of Production', *Econometrica*, 12, pp. 143–2005.

Melitz, M.J. (2003): 'The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity', *Econometrica*, 71, pp. 1695–1725.

Möhlmann, J.L., S. Ederveen, H.L.F. De Groot and G.M. Linders (2010): 'Intangible Barriers to International Trade: A Sectoral Approach', in: P.A.G. Van Bergeijk and S. Brakman (eds.), *The Gravity Model in International Trade: Advances and Applications,* Cambridge University Press, Cambridge.

Olley, S. and A. Pakes (1996): 'The Dynamics of Productivity in the Telecommunications Equipment Industry', *Econometrica*, 64, pp. 1263–1297.

Olsen, K.B. (2006): *Productivity Impacts of Offshoring and Outsourcing: A Review*, OECD STI Working Paper, 2006/01, Paris.

Pavitt, K. (1984): 'Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory', *Research Policy*, 13, pp. 343–373.

Petrin, A., B.P. Poi and J. Levinsohn (2003): 'Production Function Estimation in Stata Using Inputs to Control for Unobservables', *Stata Journal*, 4, pp. 113–341.

Ricardo, D. (1817): *On the Principles of Political Economy and Taxation*, John Murray, London.

Rogers, W.H. (1993): 'Regression Standard Errors in Clustered Samples', *Stata Technical Bullitin*, 13, pp. 19–23.

Statistics Denmark, Statistics Finland, Statistics Netherlands, Statistics Norway and Statistics Sweden (2008): *International Sourcing: Moving Business Functions Abroad*, Statistics Denmark, Copenhagen.

Syverson, C. (2011): 'What Determines Productivity?', *Journal of Economic Literature*, 49, pp. 326–365.

Van Gorp, D.M. (2010): *Offshoring by Manufacturing and Service Firms in the Netherlands: Offshoring Behavior in Times of a Financial Crisis*, Nyenrode Business University, Breukelen.

Wagner, J. (2011): 'Offshoring and Firm Performance: Self-Selection, Effects on Performance, or Both?', *Review of World Economics*, 147, pp. 217–247.

Wedervang, F. (1965): *Development of a Population of Industrial Firms*, Scandinavian University Books, Oslo.

Williams, R.L. (2000): 'A Note on Robust Variance Estimation for Cluster-Correlated Data', *Biometrics*, 56, pp. 645–646.

Appendix A Survey on outsourcing

This appendix contains the question from the Dutch survey that was most relevant for this paper. The full set of questions from Eurostat can be found in Statistics Denmark et al. (2008).

Welke activiteiten heeft uw bedrijf verplaatst, binnen of buiten de ondernemingengroep, in de periode 2001–2006?
(aankruisen wat van toepassing is)

	Verplaatst		**Niet verplaatst**
	Binnen Nederland	**Internationaal**	
Hoofdactiviteit			
Productie van goederen en diensten voor de markt	□	□	□
Ondersteunende activiteiten, zoals:			
Distributie en logistiek	□	□	□
Marketing, verkoop en aftersales diensten, inclusief helpdesks en callcenters	□	□	□
ICT diensten	□	□	□
Administratieve en staffuncties	□	□	□
Constructie en gerelateerde diensten	□	□	□
Research & Development	□	□	□
Andere functies of activiteiten, namelijk:	□	□	□

Appendix B Sectoral classification

The sectors used in this paper are defined based on the SBI 1993 (Standaard Bedrijfsindeling 1993) classification, which is used by Statistics Netherlands.[6] Table B1 shows which SBI 1993 codes are used for each of these sectors.

[6] This classification is very similar to the classifications from the European Union (nomenclature statistique des activités économiques dans la Communauté Européene, NACE) and from the United Nations (international standard industrial classification of all economic activities, ISIC). The first two digits of SBI 1993 are the same to those of NACE revision 1 and ISIC revision 3.

Table B1. Sectoral classification based on SBI 1993

	SBI 1993 codes	Observations used for estimating production functions	Observations available in outsourcing survey
Agriculture, forestry and fishing	01, 02, 05	0	0
Mining and quarrying	10, 11, 14, 23	1,099	3
Food, beverages and tobacco	15, 16	14,427	58
Textile, clothing and leather products	17, 18, 19	6,390	10
Wood, paper and printing	20, 21, 222	19,043	42
Chemical products, rubber and plastic products	24, 25	10,617	81
Other manufacturing (non-metallic mineral products, recycling, utilities)	26, 37, 40, 42	5,669	25
Basic metals and metal products	27, 28	19,043	54
Machinery and equipment	29	13,492	79
Office, electrical and communication machinery, medical instruments	30, 31, 32, 33	9,152	46
Motor vehicles and other transport equipment	34, 35	5,244	27
Other goods	36	5,572	41
Construction	45	63,681	58
Reparation and selling of motor vehicles	50	14,036	16
Wholesale trade	51	78,312	60
Retail trade	52	41,373	27
Hotels and restaurants	55	13,157	12
Transportation	60, 61, 62	18,116	33
Transport and travel services	63	7,863	19
Post and communication	64	1,933	9
Financial services	65, 66, 67	0	0
Real estate and renting	70, 71	4,634	13
Computer services	72	12,245	48
Other business services	73, 74, 221, 223	64,923	241
Government, education, health and social work	75, 91, 80, 85	0	0
Other services (waste disposal, recreational activities, and not elsewhere specified)	90, 92, 93	19,043	0
Total		429,505	1,002

The classification shown in Table B1 is the same sectoral classification that is used for estimating the production functions and total factor productivity (TFP). The classification is chosen in such a way that each sector has a sufficiently large number of observations in the general population of Dutch firms to allow estimating the sectoral production function. In the case of the outsourcing survey, it is possible that some sectors have a very small number of observations.

Appendix C Overview of sample used for estimating production functions

The production functions are estimated using all firms in the Netherlands for which the KLEMS data were available. Since the estimation required positive values for value added, capital inputs, labour inputs and intermediate inputs, we removed firms that had a non-positive or missing value for at least one of these variables.[7] About 430 thousand observations remained, with an average number of observations of almost 27 thousand per year. Table C1 shows the number of observations in each year, as well as the average value of each of the key variables. All values are adjusted to 2008 euros, using the Dutch consumer price index (CPI) from Statistics Netherlands (CBS).

[7] Value added is not a variable in the original KLEMS database. We defined it as the difference between production (Q) and intermediate inputs ($E + M + S$).

Table C1. Number of observations and averages of key variables over time, 2008 prices

Year	Observations	Value added (x 1000)	Capital costs (x 1000)	Labour costs (x 1000)	Intermediates costs (x 1000)
1993	9,750	5,255	1,373	3,795	12,960
1994	8,641	6,073	1,513	4,041	15,187
1995	23,494	4,051	936	2,567	7,248
1996	22,391	3,572	851	2,309	7,568
1997	21,176	3,814	875	2,395	8,246
1998	20,159	4,022	984	2,528	8,628
1999	17,786	3,632	845	2,223	6,665
2000	33,086	4,384	1,202	2,487	7,846
2001	39,865	4,004	1,573	2,351	6,964
2002	38,135	4,145	1,543	2,450	6,842
2003	38,772	4,061	1,213	2,398	6,326
2004	32,951	4,910	1,328	2,805	7,831
2005	32,363	5,166	1,364	2,896	8,633
2006	29,496	5,830	1,083	3,178	10,293
2007	29,885	6,144	1,069	3,230	10,729
2008	31,555	6,028	1,070	3,225	10,511
1993–2008	429,505	4,657	1,199	2,714	8,384

Table C2 shows the number of observations for each sector, as well as the average value of each of the key variables. The sector classification is based on the SBI 1993 classification. Appendix B shows which SBI 1993 codes are classified in which sector.

Table C2. Number of observations and averages of key variables by sector, 1993–2008 (2008 prices)

Sector	Obser-vations	Value added (x 1000)	Capital costs (x 1000)	Labour costs (x 1000)	Intermedi-ates costs (x 1000)
Agriculture, forestry and fishing	0				
Mining and quarrying	1,099	100,485	20,994	11,879	251,563
Food, beverages and tobacco	14,427	12,394	2,237	4,969	36,185
Textile, clothing and leather products	6,390	2,338	497	1,616	5,420
Wood, paper and printing	19,043	4,046	838	2,847	9,075
Chemical products, rubber and plastic products	10,617	13,494	4,192	6,879	43,591
Other manufacturing (non-metallic mineral products, recycling, utilities)	5,669	5,333	1,326	3,214	9,234
Basic metals and metal products	19,043	4,046	838	2,847	9,075
Machinery and equipment	13,492	4,914	803	3,305	9,761
Office, electrical and communication machinery, medical instruments	9,152	9,196	1,818	6,537	18,550
Motor vehicles and other transport equipment	5,244	8,597	2,037	4,968	25,154
Other goods	5,572	2,488	489	1,731	4,457
Construction	63,681	2,661	404	2,111	6,278
Reparation and selling of motor vehicles	14,036	2,968	490	1,369	3,627
Wholesale trade	78,312	3,505	762	1,922	3,435
Retail trade	41,373	3,011	1,024	2,005	2,028
Hotels and restaurants	13,157	1,878	541	1,287	2,200
Transportation	18,116	4,725	1,958	3,553	8,680
Transport and travel services	7,863	5,890	2,084	2,976	12,044
Post and communication	1,933	49,542	39,866	18,198	49,093
Financial services	0				
Real estate and renting	4,634	5,861	4,579	1,021	5,791
Computer services	12,245	4,300	737	3,289	3,786
Other business services	64,923	3,566	462	2,625	3,845
Government, education, health and social work	0				
Other services (waste disposal, recreational activities, and not elsewhere classified services)	19,043	4,046	838	2,847	9,075
All sectors	429,505	4,657	1,199	2,714	8,384

Table C3 shows how often firms occur in the data. In the period 1993–2008 we have data for about 153,000 unique firms. For almost half of them (about 71,000), we only have one year available. The other firms can be traced over at least two years. The average number of observations per firm is 2.8. Almost 400 firms are included in the data for every year in the period 1993–2008. Note that the survey is biased towards larger firms. Statistics Netherlands attempts to survey the largest firms in every year. Smaller firms are randomly selected every year.

Table C3. Number of observations per firm

Available years	Number of firms	Observations (column 1 x column 2)
1	70,693	70,693
2	28,159	56,318
3	16,920	50,760
4	10,239	40,956
5	6,899	34,495
6	4,945	29,670
7	3,806	26,642
8	2,780	22,240
9	2,234	20,106
10	1,537	15,370
11	1,169	12,859
12	1,034	12,408
13	906	11,778
14	892	12,488
15	430	6,450
16	392	6,272
Total	153,035	429,505

Appendix D Technical description of the Levinsohn and Petrin (2003) method

This appendix describes the Levinsohn and Petrin (2003) estimation method for the case where value added is a function of capital and labour, as it was described by Petrin et al. (2003). Assuming a Cobb-Douglas functional form, the relationship between these variables, in natural logarithms, is as follows (ignoring the firm subscript):

$$va_t = \beta_0 + \beta_l l_t + \beta_k k_t + \omega_t + \eta_t, \tag{6}$$

where ω_t is the productivity component that is observed by the firm, and hence correlated with inputs, and where η_t is an error term, uncorrelated with inputs.

It is assumed that k_t and ω_t are state variables and that the firm decides on its use of intermediates based on these variables:

$$i_t = i_t\left(k_t, \omega_t\right). \tag{7}$$

Petrin et al. (2003) show that, under reasonable assumptions, the demand for intermediates i_t is monotonically increasing in ω_t, so that ω_t can be written as a function of k_t and i_t:

$$\omega_t = \omega_t\left(k_t, i_t\right). \tag{8}$$

The method consists of two stages. Stage one estimates the coefficient for labour, while stage two estimates the coefficient for capital. In the first stage, the production function for value added is rewritten to:

$$va_t = \beta_l l_t + \phi_t\left(k_t, i_t\right) + \eta_t, \text{ with} \tag{9}$$

$$\phi_t\left(k_t, i_t\right) = \beta_0 + \beta_k k_t + \omega_t\left(k_t, i_t\right). \tag{10}$$

Now, $\phi_t(k_t,i_t)$ can be approximated as a third-order polynomial in k_t and i_t, so that va_t can be estimated using OLS, yielding a consistent estimator for β_l. In the second step, the estimates of step one are used to determine the prediction of ϕ_t:

$$\hat{\phi}_t = \hat{v}a_t - \hat{\beta}_l l_t. \tag{11}$$

The predicted values of ω_t can be written as a function of any value of β_k^*:

$$\hat{\omega}_t = \hat{\phi}_t - \beta_k^* k_t. \tag{12}$$

It is assumed that ω_t is a function of its previous value and a shock in productivity:

$$\omega_t = E\left[\omega_t \mid \omega_{t-1}\right] + \xi_t. \tag{13}$$

They estimate the expectation of ω_t as a third order polynomial of ω_{t-1}:

$$\widehat{E[\omega_t \mid \omega_{t-1}]} = \gamma_0 + \gamma_1 \omega_{t-1} + \gamma_2 \omega_{t-1}^2 + \gamma_3 \omega_{t-1}^3. \tag{14}$$

Finally, $\hat{\beta}_k$ is defined as the value of β_k^* that minimizes the squared differences of the actual va_t and the predicted va_t:

$$\min_{\beta_k^*} \sum_t \left(va_t - \hat{\beta}_l l_t - \beta_k^* k_t - \widehat{E[\omega_t \mid \omega_{t-1}]} \right)^2. \tag{15}$$

Publisher:

CPB Netherlands Bureau for Economic Policy Analysis
P.O. Box 80510 | 2508 GM The Hague
T (070) 3383 380

August 2013 | ISBN 978-90-5833-607-1