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ABSTRACT

Do Foreign Experts Increase the Productivity of Domestic Firms?[*]

While most countries welcome (and some even subsidise) high-skilled immigrants, there is very limited evidence of their importance for domestic firms. To guide our empirical analysis, we first set up a simple theoretical model to show how foreign experts may impact on the productivity and wages of domestic firms. Using matched worker-firm data from Denmark and a difference-indifferences matching approach, we then find that firms that hire foreign experts – defined as employees eligible for reduced taxation under the Danish "Tax scheme for foreign researchers and key employees" – both become more productive (pay higher wages) and increase their exports of goods and services.

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1. Introduction

There is ample evidence documenting that global firms are more productive than purely local firms: foreign-owned companies are more productive than domestic companies (see, *e.g.*, Lipsey, 2004); exporting firms are more productive than non-exporting firms (see, *e.g.*, Bernard and Jensen, 1995, and Bernard *et al.*, 2007); and firms that offshore internationally are more productive than non-offshoring firms (see, *e.g.*, Hummels *et al.*, 2011). In this paper, we consider yet another possible channel through which global firms may become more productive than non-global firms, namely by employing foreign experts.

The importance of foreign experts for the performance of firms is also interesting from a policy point of view. Despite widespread restrictions on international migration of labour, most countries welcome these highly qualified immigrants. Some countries even subsidise immigrants if their qualifications are sufficiently high. In, *e.g.*, Denmark, Italy, Spain, Sweden and The Netherlands, foreign labour with sufficiently high qualifications are offered special tax breaks. An important question is therefore whether these experts are in fact particularly valuable for the host countries.

In our empirical analysis, we employ a matched worker-firm longitudinal data set covering the total Danish population of workers and private firms for the years 1995-2007, and we define foreign experts as employees eligible for reduced taxation under the Danish "Tax scheme for foreign researchers and key employees". Using a difference-in-differences matching approach, we find evidence that firms become more productive and increase their export activities when hiring foreign experts.

Lazear (1999) has previously argued that a firm may become more productive from using foreign labour, if the foreign workers have information which is complementary to that of the native workers. For this to be the case, the information sets of foreign and native workers should be disjoint but relevant to each other. This information complementarity may play a role for all types of labour, but it is likely to be most important among highly skilled

workers, where specialized knowledge plays an important role. In this paper, we therefore restrict attention to a relatively small group of immigrant workers, the foreign experts.

In the literature, there are several models that feature strong complementarities between different types of inputs. One is the so-called O-Ring theory by Kremer (1993), where the productivity of workers in some tasks is strongly increasing in the productivity of workers in other tasks. With the purpose of guiding our subsequent empirical analysis, we extend the O-Ring theory to the case of expert workers using the ideas from Lazear (1999). Our model shows how a limited number of foreign experts in a firm may have a profound impact on the realised total factor productivity and profitability of the firm. Furthermore, if wages are firm specific due to, *e.g.*, rent sharing – and there is solid evidence pointing to that – the use of foreign experts will also manifest itself in higher wages for the employees.

Since our data set does not contain the required information (capital) to calculate total factor productivity (TFP) at the firm level, we focus on wages in the empirical analysis. This also comes with the additional advantage that wages are measured with much more precision than TFP. The disadvantage of using wages is, of course, that they only constitute an indirect measure of firm productivity. However, as we find that foreign experts actually increase firm-specific wages, it is a strong indication that these experts also affect the underlying productivity of the firms.

When we distinguish between the wage effects of foreign experts on different types of native workers, we find that the use of foreign experts tends to increase the wages of high-skilled workers, while there are no significant effects on low-skilled workers. This is consistent with rent sharing being most important for the group of high-skilled workers as these are harder to replace due to the strong complementarities between their specific types of skills.

One particular channel through which foreign workers may improve the performance of a domestic firm is knowledge of foreign markets (Lazear, 1999). Such knowledge will be relevant if the firm wants to expand its export activities. We test this hypothesis, and find that when a foreign expert is hired, this is followed by an increase in exports.

There already exists an extensive literature on how immigrant workers affect wages and employment of native workers; see, *e.g.*, Card (1990, 2001) and Borjas (2003). However, in most of these studies, immigrants are simply assumed to increase the labour supply. Ottaviano and Peri (2008) allow for some imperfect substitution between native and immigrant workers, but they do not consider the possibility that foreign experts may play a special role for the productivity of domestic firms. To the best of our knowledge, only Markusen and Trofimenko (2009) consider this issue. They set up a theoretical model where foreign experts may teach local employees new "tricks" and in this way increase their productivity. Using data on Columbian firms, they find that the employment of foreign experts increases firm productivity and wages of the local employees.[1]

The idea that foreign experts raise the productivity of local workers by teaching them new "tricks" seems most relevant in the context of developing countries. However, our results show that even in a high-income country, there may be gains from introducing foreign experts in a firm.

The rest of the paper is structured as follows. In Section 2, we discuss the theoretical background. Section 3 outlines the empirical framework, and Section 4 presents the data. Section 5 contains the empirical analysis, and Section 6 concludes.

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[1] There also exists a literature that analyses the importance of ethnic diversity (see Alesina and La Ferrara, 2005) and labour diversity more generally (see, *e.g.*, Barrington and Troske, 2001, Hamilton *et al.*, 2004, Iranzo *et al.*, 2008, Navon, 2009, and Parrotta *et al.*, 2010) for the productivity of firms.

2. Theoretical background

The main contribution of this paper is to provide empirical evidence of the effects of hiring foreign experts on firm performance. In order to guide our empirical analysis in terms of modelling approach and choice of control variables, this section outlines an O-Ring model extended to the case of foreign experts. Below, we provide a brief account of the main assumptions and predictions, while the details of the model are relegated to an appendix.

If foreign experts should improve the overall performance of a firm, they should be complementary to other inputs in the firm. Lazear (1999) discusses some quite general conditions under which foreign workers and native workers constitute complementary inputs in the production process. He also argues that it is costly to include workers from different countries in the same organization as different languages and different cultures must be integrated. The importance of complementarities vs. the cost of communication determines whether a firm gains from using foreign workers.

A well-known theory of complementarities between skills is the so-called O-Ring theory by Kremer (1993), where the productivity of a worker is strongly increasing in the productivity of her co-workers.[2] As a consequence, high-skilled workers tend to cluster in some firms and low-skilled workers in other firms.[3] Specifically, the O-Ring model assumes that the production process consists of many strongly complementary tasks, where the probability of successful completion of a task depends on the quality (skills) of the worker(s)

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[2] Other theories suggesting strong complementarities between different types of inputs include Sattinger (1979), Milgrom and Roberts (1990), Grossman and Maggi (2000), Acemoglu *et al.* (2007) and Jones (2011). Verhoogen (2008) and Kugler and Verhoogen (2011) document complementarities between the quality of inputs and plant productivity.

[3] This clustering tendency has recently been used in several studies of migration building on the O-Ring theory. In Hendricks (2001) it is used to explain why new immigrants tend to cluster in locations with a high concentration of previous immigrants of the same nationality. Gianetti (2003) uses the clustering result to explain why high-skilled workers tend to migrate to rich regions, and Kreickemeier and Wrona (2011) apply it in a context where high-ability workers select into being emigrants (which is costly) in order to signal to firms that they are high-quality workers.

assigned to the task, and the model does not allow quantity to substitute for quality within a task.

In our paper, the strong complementarities of the O-Ring model are used to argue why foreign experts may increase the overall productivity of a firm. We extend the model by Kremer (1993) in four important ways.

First, we introduce a horizontal dimension in the skill composition of educated workers in addition to the vertical dimension used in the original model. Specifically, we assume that among workers with a certain level of skills (the vertical dimension), there is a difference with respect to how well their specific types of skills fit the needs of a given firm (the horizontal dimension). As an example, consider two persons who both hold an MBA from a prestigious business school, and who both have 10 years of management experience from successful companies. The market value of these two persons may be identical, but they may not fit the needs of a specific company equally well. Such a horizontal difference could be due to different specializations across business schools or between programs within schools, or it could be due to work experience from different types of firms. Thus, an important difference between the vertical skill dimension and the horizontal skill dimension is that the vertical dimension can be measured by the market value of a worker, whereas the horizontal dimension is often impossible to measure directly in empirical analyses. Instead, the ability to find the right skills in the horizontal dimension will show up in the observed total factor productivity (TFP) of the firm. Note that the horizontal dimension is assumed only to apply to the high-skilled (educated) workers, as these are the ones that handle the specialized tasks in the firm.

The existence of a horizontal dimension is also consistent with a narrow interpretation of the skill-weights view of human capital by Lazear (2009). In this model, firms may differ

in their labour demand, such that some firms demand workers with a specific combination of general skills, *e.g.*, a certain MBA combined with experience from a given industry.

Second, in line with Lazear (1999), we assume that it is costly to hire foreign experts. Along the horizontal dimension, firms seek to employ workers with skills as close as possible to the ideal skills required to perform the task in question, and the thicker the market is, in which firms are searching, the more likely the firm will be to find a candidate with ideal or "close-to-ideal" skills. Hence, a firm that searches in both foreign and local markets has a better chance of finding a candidate with the right skills than a firm that searches only in local markets. However, searching in foreign labour markets is more costly than searching only in local markets, and it may also be more costly to hire a foreigner than a local worker.

In the real world, the search-and-hiring cost of a firm may reflect a number of different things, including (but not limited to) the legal set-up such as tax breaks and immigration laws that affect the cost of searching for and hiring foreign workers; the international network/contacts of the firm which are influenced by, *e.g.*, the mix of native employees; and pure luck in the sense that some firms are approached by relevant foreign workers or run into them accidentally at conferences or trade fairs. For these reasons, we assume that the cost of searching for and hiring foreign experts varies across firms.

Third, in the spirit of Melitz (2003) and a large subsequent theoretical and empirical literature, we also assume that firms are heterogeneous with respect to an exogenous productivity parameter. That is, some firms are inherently more productive than other firms, *e.g.*, because they have a better "business idea" or a more able manager. Observed TFP then depends both on the exogenous productivity parameter and the match quality in the horizontal dimension, *i.e.*, whether the firm hires foreign experts.

Finally, wages are assumed to be firm specific for the skilled workers. Firm-specific wages may arise if firms have monopsony power in the labour market (Manning, 2003).

Recent evidence suggests that such firm-specific labour supply curves actually do exist; see, *e.g.*, Falch (2010) and Staiger *et al.* (2010). Alternatively, firm-specific wages may be the result of imperfectly competitive goods markets and rent sharing between firms and workers, either through bargaining or efficiency wages; see, *e.g.*, Egger and Kreickemeier (2009) and Amiti and Davis (2011). There is also considerable evidence of this taking place in practice; see, *e.g.*, Blanchflower *et al.* (1996), Hildretch and Oswald (1997) and Arai (2003).

In the appendix, the firm-specific wages are modelled as the result of rent sharing between the firm and the skilled workers. We assume that low-skilled workers are excluded from the rent sharing because they are easier to replace as they do not differ in the horizontal dimension. As a consequence, an increase in the variable profits of the firm leads to an increase in the firm-specific skilled wages.[4]

As shown in the appendix, the model implies the existence of a critical value of the firm-specific search-and-hiring cost such that only firms with costs below this level will extend their recruitment efforts to foreign markets. It is also shown that the critical value depends negatively on the exogenous firm-specific productivity parameter, due to a complementarity between this parameter and the quality of the horizontal match. For the same reason, the costs of other inputs also affect the critical value. Hence, firms with a low search-and-hiring cost or with a high exogenous productivity parameter will extend their search for skilled workers to foreign markets, and will therefore be more likely to employ foreign experts. As a consequence, these firms will have higher levels of variable profits and observed TFP, and they will also pay higher (skilled) wages than otherwise similar firms that do not try to recruit in foreign markets.

An implication of the model is that firms can start employing foreign experts for three different reasons (or a combination of these). First, a drop in the firm-specific search-and-

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[4] Assuming firm-specific labour supply curves instead of rent sharing between firms and workers would yield qualitatively similar results.

hiring cost that takes it below the critical value will cause a firm to start recruiting foreign experts, thereby causing an increase in observed TFP, profits and (skilled) wages of the firm. Due to the strong complementarities between the different inputs, the size of these effects will depend on the initial characteristics of the firm (which in turn are determined by the exogenous productivity parameter).

Second, the employment of a foreign expert may be the result of an increase in the exogenous productivity parameter, as this lowers the firm-specific critical value by making it more important for the firm to obtain a better horizontal quality of labour input. In this case, observed productivity, profits and (skilled) wages will increase for all firms experiencing an increase in their exogenous productivity, but more if it also induces the firm to recruit foreign experts.

Third, changes in general framework conditions such as the cost of capital or the general wage level will affect the critical values of all firms but only cause some of them (the marginal ones) to start recruiting foreign experts. As in the second case, the performance of all firms will be affected, but more positively for those who start recruiting foreign experts. In all cases, the size of the effects also depends on the initial firm characteristics.

3. Empirical framework
Our theory model illustrates that firms that use foreign experts are both more productive and profitable and therefore pay higher wages than other firms. This is both because the foreign experts ensure a better match between tasks and skills, and because it is the most productive firms that benefit most from employing foreign experts. Thus, as the previous section also showed, firms may start recruiting foreign experts for three different reasons (or a combination of these): (1) a reduction in the firm-specific search-and-hiring cost; (2) an increase in the firm-specific exogenous productivity parameter; and (3) changes in the general framework conditions. In the first case, the associated changes in firm performance

can be given a causal interpretation, while in the second and third case, we need to isolate the effect of the foreign experts from the effects of the exogenous productivity increase and the changes in the framework conditions.

Hence, to identify the causal effects on firm performance from hiring foreign experts we must pay special attention to selection effects, and therefore we apply a difference-in-differences matching estimator (Heckman *et al.*, 1997). That is, we compare the change in performance in firms that hire foreign experts (the treatment group) to that in other firms which have similar initial characteristics and which realize the same exogenous changes (or lack of changes) in productivity, but where the firm-specific search-and-hiring costs remain above the critical value (the control group).

By using a difference-in-differences approach, we eliminate the effects of time-invariant factors (such as differences in exogenous productivity) and the effects of common changes in framework conditions that affect firm performance. However, as initial firm characteristics affect not only initial performance and the likelihood of hiring foreign experts (those closest to the critical value are more likely), but also the effects of hiring these, matching on these characteristics is important. Furthermore, we need also to match on exogenous productivity changes as these affect both observed performance, the likelihood of hiring foreign experts and the effects of these.

Matching on the exogenous productivity development is, of course, complicated by the fact that the exogenous part of productivity is unobservable, and the literature on production-function estimation has long struggled with this issue using different proxies for exogenous productivity shocks; see, *e.g.*, Olley and Pakes (1996) and Levinsohn and Petrin (2003). What we do is to use the employment of native experts as a proxy for exogenous increases in productivity. Hence, we require that the firms in the control group also hire new experts, but local experts instead of foreign experts. In this way, our control firms are also

likely to have been hit by a positive productivity shock, but choose to stick to domestic experts. Furthermore, we match on the initial average wage growth in the firm, taking this as an indicator of the historical productivity growth in the firm and therefore as a prediction of future exogenous productivity growth as well.

Matching with many covariates, as in our case, leads to a dimensionality problem, so we use the propensity score method (Rosenbaum and Rubin, 1983) to summarise the vector of matching characteristics, X, into a single-index variable, the propensity score, $P(X)$. The propensity score is the conditional probability that a firm hires a foreign expert. The first step in the matching analysis is to estimate the propensity score for the firms in the treatment and the control groups using a probit model. In Section 5, we discuss in detail the variables included in the model.

Having estimated the propensity score for all treatment and control firms, we can estimate the average effect of hiring foreign experts among the treated firms, the so-called "average effect of treatment on the treated" (ATET). This is done by comparing the change in performance of a treated firm with the change in performance of one or more firms in the control group with similar propensity scores. In this way, we compare the change in performance in firms which have similar initial characteristics.

Specifically, the matching difference-in-differences (MDID) estimator takes the following form:[5]

$$\delta_{MDID} = \frac{1}{N_1}\sum_{j\in I_1\cap S_P}\left(\Delta W_j - \sum_{i\in I_0}\omega(i,j)\Delta W_i\right) \tag{1}$$

where ΔW_j denotes the difference in the wage level (or another measure of firm performance) in firm j before and after a foreign expert is hired, and I_1 and I_0 are the sets of treatment and control firms, respectively. N_1 is the number of firms in the set $I_1 \cap S_P$, where

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[5] See Blundell and Costa-Dias (2009) for a recent exposition of the MDID estimator.

S_P denotes the common support region of the propensity score. Hence, $I_1 \cap S_P$ is the set of treatment firms for which a matching control firm can be found. The weights, $\omega(i,j)$, are constructed such that they depend on the distance in propensity scores between firm j and firm i. We implement two different matching estimators to construct the weights: the standard nearest-neighbour matching estimator, where only one comparison firm is used (the one with the propensity score closest to the treatment firm), and the local-linear matching estimator where multiple comparison units are used (and where the weights are inversely proportional to the distance).

4. Data

We have access to a very rich matched worker-firm longitudinal data set covering the total Danish population of workers and firms for the years 1995-2007. The data are drawn from several administrative registers in Statistics Denmark. The source of the firm data is the Firm Statistics Register (FirmStat), which provides annual information on industry affiliation (six-digit NACE code), the number of full-time employees, sales and export volume. FirmStat associates each firm with a unique identifier, which allows us to track the same firm over time.

Detailed information on individual socio-economic characteristics is available on an annual basis. There is information about, *e.g.*, age, sex, citizenship, labour market experience, tenure, education and a wage rate calculated as annual labour income divided by annual working hours. In the following, we distinguish between high-skilled, medium-skilled and low-skilled workers. High-skilled workers refer to persons with a tertiary education according to the International Standard Classification of Education (ISCED). Medium-skilled workers have a vocational education defined as the final stage of secondary education that prepares students for entry into the labour market. Finally, persons with the equivalent of high school education or less are classified as low-skilled workers. These individual level

variables are extracted from the integrated database for labour market research (IDA) and the income registers in Statistics Denmark. IDA also associates each person with a unique identifier, which allows us to track workers over time.

To match the firm data with the worker data we draw on the Firm-Integrated Database for Labour Market Research (FIDA), which for a given year links every firm in FirmStat with all the workers in IDA who are employed by that firm in week 48 of the given year.

4.1 Foreign experts

Our data on foreign experts are provided by the Danish tax authorities who record information about firms hiring foreign experts that are eligible for reduced income taxation under the "Tax scheme for foreign researchers and key employees". This data set uses the same firm and worker identifiers as FIDA, allowing us to match the data with our worker-firm data on an annual basis.

The tax scheme was introduced in 1992 and applies a flat tax rate of 25 %, which is much lower than the normal tax rates in the Danish tax system (the highest marginal tax rate was around 60 % in the period under consideration). The scheme was changed in 2002. Before 2002, foreign experts were eligible for the reduced tax rate for the first three years, but if their stay in Denmark extended seven years, they were liable to pay a reimbursement tax equivalent to the subsidy obtained in the first three years. In 2002 this reimbursement tax was abolished such that the foreign experts can now stay in Denmark as long as they wish without paying any additional taxes to compensate for the subsidy in the first three years. As this change makes it easier to attract foreign experts, it ensures some exogenous variation in the search-and-hiring costs of the firms in the period under consideration.

To be eligible for the reduced tax rate some requirements must be met. The most important ones are the following. First, the employee should not have been liable to pay taxes in Denmark for the previous three years. This implies that not only foreigners but also Danes

who have stayed abroad for more than three years may be eligible for the reduced tax rate. Throughout this paper, we include these persons among the "foreign" experts, as they must all be recruited from abroad, and hence are likely associated with higher search-and-hiring costs than truly domestic experts. The second requirement is that it does not count as years abroad if a person was expatriated by his or her Danish employer. Third, the monthly salary of the person should be above a threshold level which in 2007 was DKK 65,408 (corresponding to around 8,800 Euros). Hence, this threshold level of income is effectively what defines an expert, *i.e.*, a person who has a sufficiently high productivity to command this salary. It should be mentioned that foreign experts may be eligible for the low tax rate in jobs paying wages below the threshold level, if they are employed by a university or a research institution. However, in the following we restrict attention to the foreign experts employed in private firms, where they are all required to have a wage higher than the threshold level.

In Figure 1, we illustrate the development in the number of foreign experts in private firms. It is a relatively low number of employees who by our definition are foreign experts. In 1995 there were around 600, and this number had increased to around 1700 in 2007. Most of the foreign experts are hired in the service sector; only one quarter is employed in manufacturing.

INSERT FIGURE 1 HERE

Table 1 illustrates the distribution of the foreign experts over origin countries (citizenship) in 1995 and 2007. The countries are ranked according to their share of the foreign experts in 2007. In 2007, 20 % of the foreign experts had Danish citizenship. These are Danes who have been working abroad for at least 3 years prior to their current employment. In 1995, only 3 % of the foreign experts were Danes. This development could be explained by the change in the programme in 2002, as it is likely to be more valuable for

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Danes that they can stay in Denmark for more than seven years without having to pay back the subsidy obtained in the first three years. The other main suppliers of foreign experts to Danish firms are the neighbouring countries, Germany and Sweden, followed by the UK and the US. In 2007, all other countries each contributed with less than 5 % of the foreign experts.

INSERT TABLE 1 HERE

Table 2 illustrates the distribution of foreign experts across industries. The industries are ranked according to their share of the foreign experts in 2007. It is somewhat surprising that 16 % and 35 % of the foreign experts were employed within *Wholesale and commission trade* in 1995 and 2007, respectively. The other industries that employ many foreign experts are R&D-intensive industries and industries where the quality of the good is likely to depend on the input of very specialized skills. This is, in particular, the case within *Manufacture of chemicals and chemical products, Computer and related activities* and *Research and development*.

INSERT TABLE 2 HERE

The data also allow us to analyse whether foreign and domestic experts are employed in similar occupations. In the following, we define domestic experts as native employees receiving a wage above the level required to be eligible for the reduced tax scheme for foreign workers. Not surprisingly, both foreign and domestic experts are employed in more advanced occupations such as *Managers*, *Professionals*, and *Technicians and associate professionals*; see Table 3. However, foreign experts are slightly more concentrated in the top-2 occupations (*Managers* and *Professionals*) than domestic experts. This is consistent with foreign experts earning somewhat higher wages despite being of roughly the same age and gender composition as domestic experts; see Table 3.

INSERT TABLE 3 HERE

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4.2 Firms with foreign experts

In the following, we focus on private sector firms with at least 10 full-time employees, as the use of experts is likely to play a different (less specialized) role in smaller firms. Table 4 displays the total number of firms in our sample (column 1), the number of firms with foreign experts (column 2) and the number of firms with domestic experts (column 3). Only a minority of the firms have foreign experts in their workforce – less than 600 out of approximately 20,000 firms employ foreign experts in 2007. In contrast, around half of the firms use domestic experts.

INSERT TABLE 4 HERE

The fourth column of Table 4 shows the number of firms that start to use foreign experts in a given year. These observations will constitute the treatment group in the matching analysis below. A firm is classified as a treatment firm if the following three conditions are met: (i) it should be observed in at least five consecutive years: $t - 2$, $t - 1$, t, $t + 1$ and $t + 2$; (ii) it should not employ foreign experts in $t - 1$ and $t - 2$ (and $t - 3$ if present in that year as well); (iii) it is observed with at least one foreign expert among its employees in year t. For $t = 1998$, there are 48 firms that satisfy these conditions. In total, there are 557 firms in the treatment group in Table 4. Around 30 of these are dropped in the subsequent matching analysis because of missing observations and the common support requirement.

The observations in column 5 constitute the control group. These are firms that are observed in at least five consecutive years, $t - 2$, $t - 1$, t, $t + 1$ and $t + 2$, and which hired at least one domestic expert in year t. Note that these conditions imply that a given firm can enter the control group with more than one observation if it satisfies the above requirements for, *e.g.*, both $t = 1998$ and $t = 1999$. In column 5, there is a total of 23,791 control observations, but in the matching analysis we impose the additional requirement that these

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firms should not hire foreign experts in any of the five years or earlier sample years, which reduces the control sample to around 14,000 observations.

Firms that start to hire foreign experts are different from firms without foreign experts. Table 5 reports the results of simple regressions where the treatment and control observations are compared. The dependent variable is a firm characteristic measured in $t - 1$ (the year prior to treatment), and the explanatory variable is the treatment indicator. It is seen that firms that hire foreign experts are bigger, have higher sales, export more, use more high-skilled labour, use more domestic experts and pay higher wages. These differences persist when including industry fixed effects and firm size as additional controls, and it suggests that selection effects play an important role as predicted by our theory. Firms that hire foreign experts are on average different from firms that do not hire foreign experts, and it is necessary to appropriately control for these selection effects, if we wish to uncover the causal effects of the foreign experts.

INSERT TABLE 5 HERE

5. Results

Table 5 showed that average wages are higher in firms employing foreign experts. While this suggests a positive effect of foreign experts on firm performance, our theory model showed that the incentive to hire foreign experts is also higher in the more productive firms. To identify the causal effect of hiring foreign experts, we argued in Section 3 that we must compare the development in firms that hire foreign experts to that in other firms which have both similar initial characteristics and which realize the same exogenous changes in productivity. This section therefore contains the results of the difference-in-differences matching analysis described in Section 3.

First, we consider the effect on firm-level outcomes, in particular the average wage in the firm, from hiring foreign experts. As firm-level measures may be affected by composition

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effects, we subsequently consider the effects on individual wages. Finally, we investigate one particular channel through which foreign experts may complement other inputs: knowledge of foreign markets. To test this, we analyse whether foreign experts are used to promote exporting activities.

5.1 Firm-level outcomes

The first step in applying the MDID estimator is to predict the propensity scores for all treatment and control observations. In estimating the probit model, we include a number of initial firm characteristics measured in $t-1$ (the year before hiring foreign experts for the treatment firms) as well as a proxy for exogenous changes in productivity.

The initial firm characteristics included are expected to reflect the initial productivity level and the initial composition of factor inputs. Hence, we include the log of the average wage level as this is likely to depend on firm productivity, cf. Section 2. We also include two measures of firm size (the number of full-time employees and turnover) as size is typically found to be strongly correlated with productivity; see, *e.g.*, Oi and Idson (1999). We also include two measures of export activity (an exporter dummy and the share of exports in turnover), as exporting activity is also found to be associated with higher productivity; see, *e.g.*, Bernard and Jensen (1995) and Bernard et al. (2007). When it comes to the composition of factor inputs, we include the shares of high- and medium-skilled workers in firm employment as well as the share of domestic experts. Finally, we include year and industry dummies in the probit model.

As a proxy for the exogenous productivity development, we use the initial wage growth (between $t-2$ and $t-1$). This is an indicator of the historical productivity growth in the firm and therefore also a prediction of future exogenous productivity growth. Furthermore, control firms are all required to hire a domestic expert in period t as explained in Section 4.

Table 6 shows the results from the estimation of the probit model. It is seen that large firms with high export ratios, a large share of high-skilled workers and a high initial wage level are more likely to hire foreign experts. This is fully consistent with the theory model from Section 2. More surprisingly, the share of domestic experts and the initial wage growth rate do not significantly affect the probability of hiring a foreign expert.

INSERT TABLE 6 HERE

Having predicted the propensity scores from the probit model above, the next step is to estimate the ATET using the two matching estimators described in Section 3. However, as we are not matching directly on the covariates but on the propensity scores, it has to be checked that this procedure is able to balance the distribution of the relevant covariates among the treatment and the matched control firms.

Table 7 displays the standardized biases for the variables in the probit models when using the local-linear matching estimator. The standardized bias shows the difference in sample means in the treated and matched control subsamples as a percentage of the square root of the average of sample variances in both groups (Rosenbaum and Rubin, 1985). This is one way to evaluate the quality of the match. It is seen that matching generally reduces the bias substantially for all variables, and that the treatment and control groups are comparable after matching. In particular, there are no significant differences in covariate means for the two groups after matching.

It turns out that using nearest-neighbour matching results in a somewhat lower match quality, although the standardized bias only exceeds 10 % for two (out of 25) covariates. Hence, in the following, we present only the results from using local-linear matching. The nearest-neighbour matching results, which are very similar, are available from the authors upon request.

INSERT TABLE 7 HERE

The first row of Table 8 shows the effect (ATET) of hiring foreign experts on the change in average wages between year $t-1$ and t (the year where foreign experts are hired). We find no significant effect on this outcome, but there is a significantly positive effect of almost 2.5 % on the change in average wages between $t-1$ and $t+2$. That is, in firms hiring foreign experts, average wages increase by 2.5 % more than in similar firms hiring only domestic experts.

INSERT TABLE 8 HERE

In Table 8, it is also reported how firm-level sales, total employment and the skill composition are affected by the hiring of foreign experts. Although the effects are estimated to be insignificant, employment tends to decrease (close to being significant), while sales tend to increase (insignificantly). The combination of these two effects also suggests that productivity tends to increase in firms that hire foreign experts. Finally, Table 8 shows that the composition of workers changes within the firm such that the share of medium-skilled workers declines while the share of high-skilled workers increases. This suggests that the increase in average wages may be driven by compositional changes within the firm. We investigate this issue further in the following subsection.

5.2 Worker-level outcomes

We can exploit the wealth of information in our matched worker-firm data to circumvent the impact of within-firm compositional changes on the average wage. To do this, we focus on individual wages in the following.

In this case, the treatment and control observations consist of all workers who remain in the treatment and control firms in all five years ($t-2$ to $t+2$). This yields around 100,000 treatment observations (of which around 10 % are lost due to the common support requirement) and around one million control observations. When estimating the propensity score, we match on the same firm characteristics as above but also include a number of

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worker characteristics such as the initial wage, age, marital status, number of children, education, labour market experience, tenure in the firm, occupation, region of residence and immigrant status.[6]

When worker-level data are used, the local-linear matching method does not converge, and therefore only nearest-neighbour matching results are presented. The quality of the match for the firm-level covariates is comparable to that obtained in the firm-level analysis, while matching quality is in general better for the covariates at the worker level. Hence, only for three covariates (out of 50) do the standardized biases after matching exceed 10 %.

Table 9 shows the treatment effects on the full sample of workers remaining in their firms in at least five years. We see that in year t and $t + 2$ there are significantly positive effects on the wages of 0.2 % and 0.3 %, respectively. The effect in $t + 1$ is also positive (0.08 %) but insignificant. As the effects are considerably smaller numerically than when using average wages, it supports the idea that compositional changes are also important for the development in average wages.

INSERT TABLE 9 HERE

Table 9 also reports separate wage effects for low-skilled, medium-skilled and high-skilled workers. As expected, the wage effects are strongest and most positive for the high-skilled workers. Here the effects are in the range of 0.5-0.65 % and significant in t, $t + 1$ and $t + 2$.[7] For low-skilled workers, the effects are insignificant throughout, while the picture for medium-skilled workers is more mixed with a positive effect the first year, which turns negative in the second year, and which disappears by the third year.

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[6] Results from estimating the probit model are available from the authors upon request.
[7] The match quality is also better when considering only high-skilled workers with all standardized biases being below 10 % after matching.

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That wage effects are most pronounced for the high-skilled workers is consistent with the idea that rent sharing takes place mainly between the firms and the high-skilled workers, as these are harder to replace than the low-skilled workers, due to the strong complementarities between the specific types of skills of the high-skilled workers.

5.3 International trade effects of foreign experts

The evidence above suggests that foreign experts increase the productivity of firms. According to Lazear (1999), the reason might be that foreign experts have information which is relevant and complementary to the information of native workers. There may of course be many channels through which such complementarities can arise, but one obvious possibility is that foreign experts are used to increase export activities. This could happen if foreign workers speak the local language at export destinations or if they have special knowledge about the culture and markets which is complementary to the knowledge of native workers; se also Molina and Muendler (2010) who emphasize the importance of specific skills when exporting. The firms may also be able to exploit the network of the foreign expert at the export destination.

To analyse this, we test whether firms tend to take up or increase their exporting activities after hiring foreign experts. Table 10 shows the estimated effects on exporter status (rows 1-3) and the share of exports in total turnover (rows 4-6), using the same matching procedure as the one underlying the results in Table 8.

INSERT TABLE 10 HERE

We see that hiring foreign experts do in fact increase the probability that a firm is exporting by 2.7 percentage points the following year. The effect is still positive in the following two years but no longer significant. Moreover, we see that the export intensity increases significantly by 1.3-1.6 % in all three years following the employment of a foreign

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expert. This strongly suggests that firms use the foreign experts to increase their activities at foreign markets.

6. Conclusion

In this paper we have argued that there may exist strong complementarities between the knowledge (skills) of foreign experts and native workers in a company. In this case, a few foreign experts may give rise to a significant increase in firm productivity. By applying difference-in-differences matching techniques to a rich Danish data set, we find support for this prediction. The average wage level in the firm increases significantly by 2.4 % in the third year following the employment a foreign expert. We take this as evidence of a positive productivity effect.

Using worker-level information, we find that wages increase significantly in both the first and the third year after the foreign expert has arrived, and when we distinguish between different types of worker, we find that the effect is strongest (0.5-0.65 %) and most significant for the high-skilled workers. The latter is fully consistent with rent sharing being most relevant for the high-skilled natives workers, as these are the ones for which strong complementarities exist and hence are more difficult to replace than low-skilled native workers. The fact that average wages increase more than individual wages also indicate that an upgrade in the composition of firm employment takes place following the employment of a foreign expert.

One reason why firms may benefit from foreign workers is that these possess special knowledge about foreign markets. This hypothesis is confirmed by our study as the hiring of foreign experts both raises the probability of exporting the following year by 2.7 percentage points and the intensity of exports by 1.3-1.6 % in the three following years.

Appendix

This appendix contains the formal derivation of the theory model and results from Section 2.

We assume that the production in firm j is given by:

$$y_j = A_j k_j^\alpha h_j^\beta l_j^\gamma, \tag{A1}$$

where A_j is the exogenous productivity parameter, k_j is capital, h_j is the input of skilled labour, and l_j is the input of unskilled labour.[8] The use of skilled labour is organised around a number of tasks, with the total input of skilled labour given by:

$$h_j = \left(\Pi_{i=1}^{n_j} \big(q_{ij} \cdot (1 - d_{ij}) \big) \right) \cdot s_j, \tag{A2}$$

where s_j is the number of skilled workers, and n_j is the number of tasks in firm j. q_{ij} is the (average) skill level of the workers in task i ($0 \le q_{ij} \le 1$), and d_{ij} is the (average) distance between the optimal skill type and the actual skill type in task i ($0 \le d_{ij} \le 1$). If $q_{ij} = 1$ and $d_{ij} = 0$ for all i, then workers have the highest possible skill levels as measured by q_{ij} (the vertical dimension), and their skill types perfectly match the needs of the firm as measured by d_{ij} (the horizontal dimension). In Kremer (1993), d_{ij} is implicitly equal to zero. Since s_j is the number of skilled workers employed, s_j/n_j is the number of replications of the required tasks in the firm. To simplify the exposition, we assume that n_j is exogenous and does not vary across firms, *i.e.*, $n_j = n$.

In the following, observed total factor productivity (TFP) is defined as the part of firm productivity that cannot be explained by the observed quality and quantity of inputs.[9] Ideally, the only part of the production function to be included in observed TFP is the exogenous productivity parameter, A_j. In practice, however, observed TFP will also reflect the value of the d_{ij}'s, as we cannot measure the extent to which the firm has success in hiring candidates with the optimal skill types. Similarly, observed TFP will also to some extent reflect the q_{ij}'s,

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[8] In the empirical specification, we distinguish between three skill levels of labour, but to avoid unnecessary complexity, we use only two types in the theory model.

[9] Syverson (2011) provides a recent discussion of different concepts and problems related to defining and measuring TFP.

since even when these can be observed (through wages), we do not have the required information about the number of tasks to correct for this in the measurement of TFP. To illustrate this, we can insert (A2) in (A1) and express the production function as:

$$y_j = TFP_j \cdot k_j^\alpha \cdot s_j^\beta \cdot l_j^\gamma, \tag{A3}$$

where TFP_j is the observed TFP of firm j given by:

$$TFP_j = A_j \cdot \left(\Pi_{i=1}^n q_{ij} \cdot \left(1 - d_{ij} \right) \right)^\beta \tag{A4}$$

If the price of the good produced by the firm is normalized to one, the variable profits are given by:

$$\pi_j = y_j - \left(\sum_{i=1}^n w_j\left(q_{ij}\right) + \sum_{i=1}^n c\left(E_j, d_{ij}\right) \right) \cdot \left. s_j \middle/ n \right. - w^u \cdot l_j - r \cdot k_j \tag{A5}$$

where w^u is the unskilled market wage, r is the exogenous cost of capital, and $w_j\left(q_{ij}\right)$ is the firm-specific wage of a skilled worker of quality q_{ij}. $c(E_j, d_{ij})$ is the cost of recruiting a skilled worker (of a given quality) where the distance between the optimal type and the actual type hired is d_{ij}, and E_j is a measure of the extent of the market in which firm j searches for skilled workers.[10] Specifically, we shall assume that:

$$c\left(E_j, d_{ij}\right) = E_j \cdot \left(1 - d_{ij} \right)^{n+1} \tag{A6}$$

Hence, a better match comes at a higher cost, $\partial c / \partial d_{ij} < 0$. Furthermore, the marginal cost of improving the match increases as the match gets closer to the optimal match, $\partial^2 c / \partial d_{ij}^2 > 0$.[11] However, if the firm gets access to a larger market for skilled labour (represented by a smaller value of E_j), it is able to get the same match at a lower cost, $\partial c / \partial E_j > 0$. Furthermore, access to a larger market decreases the cost of improving the match,

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[10] To be precise, q_{ij} is the *average* quality of workers in task i, and d_{ij} is the *average* distance between the optimal skill type and the actual skill type in task i. Hence, strictly speaking, $w_j(q_{ij})$ is the wage cost per worker of getting workers with an *average* quality of q_{ij}, and $c(E, d_{ij})$ is the cost per worker of recruiting skilled workers with an *average* distance of d_{ij} between the optimal and the actual types of skills in task i.

[11] The marginal cost also increases with *n,* reflecting that a larger number of different tasks make it harder to obtain a better match within a given task.

$\partial^2 c / \partial E_j \partial d_{ij} < 0$.[12] In the following, we assume that E can take only two values: $E = D$ if the firm has access only to the domestic labour market, and $E = I < D$ if the firm has access to the international market for skilled labour as well, *i.e.*, it tries to recruit foreign experts. Access to the international market is associated with a firm-specific fixed cost, c_j^f.

In order to focus on the horizontal dimension in the task quality, we let $q_{ij} = 1$ for all i and j, but we assume that the firm-specific skilled wage differs from the market wage due to rent sharing between the firm and the skilled workers:

$$w_j = w_j(1) = w^s + \varphi \pi_j^{gross}, \tag{A7}$$

where w^s is the exogenous market wage, φ is a profit sharing parameter, and π_j^{gross} is variable profits before rent sharing, *i.e.*, $\pi_j = (1 - \varphi)\pi_j^{gross}$.[13]

Under the assumption of decreasing returns to scale in all production factors, $n\beta + \beta + \alpha + \gamma < 1$, the following proposition applies:

Proposition 1

1. *There exist a critical value of the fixed cost as a function of A_j (and other parameters), $\bar{c}(A_j)$, where $\bar{c}'(A_j) > 0$, and such that firm j will try to recruit foreign experts if and only if $c_j^f \leq \bar{c}(A_j)$.*

2. *A firm j with $c_j^f < \bar{c}(A_j)$ will have a higher observed TFP, a higher profit level and a higher average wage level than another firm k with $A_k = A_j$ and $c_k^f > \bar{c}(A_k)$.*

3. *A firm j will have a higher observed TFP, profit and wage level, and a higher chance of employing foreign experts than another firm k with $c_k^f = c_j^f$ and $A_k < A_j$.*

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[12] More realistically, the *probability* of getting a better match should increase with the extent of the market. However, to keep the analytics tractable, we assume that the match improves with certainty. This assumption does not affect the results qualitatively.

[13] Alternatively, we could use variable profits net of rent-sharing in (A7), *i.e.*, $w_j = w_j(1) = w^s + \varphi \pi_j^s$. This would not qualitatively affect the results.

Proof: Using (A3), (A4), (A6) and (A7) in (A5) together with $q_{ij} = 1$ implies that variable profits can be written as:

$$\pi_j = (1 - \varphi)\left\{A_j k_j^\alpha s_j^\beta l_j^\gamma \cdot \Pi_{i=1}^n (1 - d_{ij})^\beta - rk_j - w^u l_j - w^s s_j - \frac{E_j s_j}{n}\sum_{i=1}^n (1 - d_{ij})^{n+1}\right\}$$

Due to symmetry, $d_{ij} = d_j$ for all i, and the expression for variable profits reduces to:

$$\pi_j = (1 - \varphi)\left\{A_j(1 - d_j)^{n\beta} k_j^\alpha s_j^\beta l_j^\gamma - rk_j - w^u l_j - w^s s_j - E_j s_j(1 - d_j)^{n+1}\right\} \quad \text{(A8)}$$

Now, let $\pi(A_j, E_j)$ denote the maximised value of variable profits given A_j and E_j. It follows immediately from (A8) that $\pi(A_j, I) > \pi(A_j, D)$ for all $A_j > 0$, and hence the critical value is given by $\bar{c}(A_j) \equiv \pi(A_j, I) - \pi(A_j, D)$. Furthermore:

$$\bar{c}'(A_j) = \pi'_A(A_j, I) - \pi'_A(A_j, D) = (1 - \varphi)\left(\frac{y(A_j, I) - y(A_j, D)}{A_j}\right) \quad \text{(A9)}$$

where $y(A_j, E_j)$ is the optimal production level given A_j and E_j, and where the second equality follows from applying the envelope theorem to (A8). Now, maximising variable profits in (A8) with respect to k_j, s_j, l_j, and d_j given A_j and E_j results in the following first-order condition for d_j:

$$d_j = 1 - \left(\frac{w^s n}{E_j}\right)^{\frac{1}{n+1}} \equiv d(A_j, E_j), \quad \text{(A10)}$$

and the following factor demands:

$$s_j = \left[A_j \left(\frac{w^s n}{E_j}\right)^{\frac{n\beta}{n+1}} \left(\frac{\alpha}{r}\right)^\alpha \left(\frac{\gamma}{w^u}\right)^\gamma \left(\frac{\beta}{w^s}\right)^{1-\alpha-\gamma}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} \equiv s(A_j, E_j) \quad \text{(A11)}$$

$$k_j = \left[A_j \left(\frac{w^s n}{E_j}\right)^{\frac{n\beta}{n+1}} \left(\frac{\gamma}{w^u}\right)^\gamma \left(\frac{\beta}{w^s}\right)^\beta \left(\frac{\alpha}{r}\right)^{1-\gamma-\beta}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} \equiv k(A_j, E_j) \quad \text{(A12)}$$

$$l_j = \left[A_j \left(\frac{w^s n}{E_j}\right)^{\frac{n\beta}{n+1}} \left(\frac{\alpha}{r}\right)^\alpha \left(\frac{\beta}{w^s}\right)^\beta \left(\frac{\gamma}{w^u}\right)^{1-\alpha-\beta}\right]^{\frac{1}{1-\alpha-\beta-\gamma}} \equiv l(A_j, E_j) \quad \text{(A13)}$$

From (A10)-(A13) it follows that $d(A_j, I) < d(A_j, D)$, $s(A_j, I) > s(A_j, D)$, $k(A_j, I) > k(A_j, D)$, and $l(A_j, I) > l(A_j, D)$, and hence that $y(A_j, I) - y(A_j, D) > 0$. Thus from (A9), we have $\bar{c}'(A_j) > 0$, which completes the proof of the first part of Proposition 1.

Turning to the second part, it follows immediately from (A4) using (A10) and $q_{ij} = 1$ that firm j will have higher observed TFP. Furthermore, profits will always be at least as high in firm j, and therefore variable profits will be strictly higher due to the fixed cost, c_j^f. It follows from (A7) that skilled (and hence average) wages will also be higher in firm j.

Considering the third part, we can distinguish between three situations: (a) $E_j = E_k = D$; (b) $E_j = E_k = I$; and (c) $E_j = I$, $E_k = D$. In cases a and b, the two firms chose the same levels of d and have the same likelihood of employing foreign experts, but since $A_j > A_k$, it follows from above that firm j will have higher observed TFP, profits and wages. In case c, firm j will also have a lower level of d, which further raises observed TFP and the likelihood of employing foreign experts. Furthermore, since the firm could have chosen the same strategy as firm k, total (and variable) profits must be higher in firm j. ∎

The next proposition summarises some comparative statics results, which follow in a straightforward manner from the results above and hence are stated without a formal proof.

Proposition 2

1. *A decrease in c_j^f increases the likelihood that firm j hires foreign experts and increases its observed TFP, profit and wage level.*

2. *An increase in A_j raises observed TFP, profits and wages and the likelihood that firm j hires foreign experts.*

3. *A decrease in the cost of capital and/or the wage rates may cause some firms to hire foreign experts and increase their observed TFP, profit and wage levels.*

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Table 1: Distribution of foreign experts on citizenship, 1995 and 2007.

	1995	1995 rank	2007	2007 rank
Denmark	0.028	9	0.200	1
Germany	0.069	6	0.143	2
Sweden	0.093	3	0.132	3
UK	0.266	1	0.096	4
USA	0.093	3	0.091	5
Norway	0.132	2	0.047	6
France	0.050	8	0.046	7
Netherlands	0.074	5	0.039	8
Finland	0.065	7	0.031	9
Canada	0.002	15	0.015	10

Note: See text for the definition of foreign experts. Only private sector foreign experts are included above. Information about citizenship was only available for 96 and 91 percent of the foreign experts in 1995 and 2007, respectively.

Table 2: Distribution of foreign experts on industries, 1995 and 2007.

	1995	1995 rank	2007	2007 rank
Other business activities	0.206	2	0.184	1
Wholesale and commission trade (except of motor vehicles and motorcycles)	0.349	1	0.164	2
Manufacture of chemicals and chemical products	0.029	8	0.109	3
Computer and related activities	0.032	6	0.105	4
Financial intermediation (except insurance and pension funding)	0.000	26	0.101	5
Research and development	0.000	26	0.050	6
Manufacture of electrical machinery and apparatus	0.008	14	0.044	7
Manufacture of machinery and equipment	0.032	6	0.026	8
Manufacture of medical, precision and optical instruments, watches and clocks	0.003	18	0.022	9
Manufacture of food products and beverages	0.039	4	0.019	10

Note: See text for definition of foreign experts. Industries are based on the two-digit NACE classification.

Table 3: Characteristics of foreign and domestic experts, 2007.

	Foreign experts	Domestic experts
Female (1=yes)	0.137	0.153
Average age (years)	41.3	42.1
Median hourly wage rate (Euros)	88.9	63.5
Occupational distribution:		
Managers	0.342	0.211
Professionals	0.376	0.314
Technicians and associate professionals	0.247	0.306
Clerical support workers	0.025	0.043
Service and sales workers	0.003	0.023
Skilled agricultural, forestry and fishery workers	0.000	0.001
Craft and related trades workers	0.001	0.056
Plant and machine operators and assemblers	0.000	0.023
Elementary occupations	0.006	0.022

Note: The occupational distributions are based on the one-digit ISCO classification, including only observations with non-missing occupations. See text for definition of foreign experts.

Table 4. Number of Danish private sector firms with and without foreign experts.

Year	(1) All firms	(2) Firms with foreign experts	(3) Firms with domestic experts	(4) Firms with newly hired foreign experts	(5) Firms with newly hired domestic experts
1995	16343	198	8079		
1996	16551	226	8115		
1997	16738	256	8014	48	2107
1998	17223	273	8631	42	2322
1999	19307	370	9635	47	2459
2000	19805	414	9937	64	3091
2001	19474	449	9999	71	3173
2002	19152	451	9566	70	2910
2003	18851	461	9089	66	2593
2004	18968	477	8406	77	2411
2005	19410	496	8882	72	2725
2006	20042	533	9447		
2007	20667	561	10136		

Note: The sample includes manufacturing and service firms with at least 10 employees. The firms in column 4 are firms which: (i) are observed in at least five consecutive years, t-2, t-1, t, t+1 and t+2; (ii) do not employ foreign experts in t-2 and t-1; (iii) are observed with at least one foreign expert in t. Firms in column 5 are observed in at least five consecutive years, t-2, t-1, t, t+1 and t+2, and hired at least one domestic expert in year t. See text for definition of foreign experts.

Table 5: Characteristics of firms hiring foreign experts

	(1)	(2)
Log (number of employees)	0.57	
Log (average wage)	0.13	0.13
Share of domestic experts	0.06	0.05
Share of high-skilled workers	0.11	0.09
Share of medium-skilled workers	-0.07	-0.05
Share of low-skilled workers	-0.04	-0.04
Log (turnover)	0.73	0.53
Exporter (1=yes)	0.13	0.11
Export/turnover	0.14	0.14
Controls	None	Size and industry fixed effects

Note: The coefficients are from individual regressions of the firm characteristic observed in year t-1 on the treatment indicator for hiring foreign experts in year t. The sample consists of all treatment and control observations.

Table 6: Probit model of the propensity score, firm sample.

	Coeff.	Std. Err.	z-value
Log (average wage)	0.7013	0.1592	4.41
Log (average wage growth from t-2 to t-1)	-0.0998	0.1719	-0.58
Number of employees	0.0002	0.0001	3.32
(Number of employees)^2	0.0000	0.0000	-1.57
Share of domestic experts	-0.3276	0.3271	-1.00
Share of domestic experts (t-2)	0.2840	0.2689	1.06
Share of high-skilled workers	0.3364	0.1630	2.06
Share of medium-skilled workers	-0.5714	0.1856	-3.08
Log (turnover)	0.1372	0.0178	7.71
Exporter (1=yes)	0.0200	0.0604	0.33
Export/turnover	0.4178	0.0735	5.68
Industry dummies	Yes		
Year dummies	Yes		
Pseudo R squared	0.10		
Observations	14221		
Treated	528		
Control	13693		

Note: See text for definition of treatment and control firms. The explanatory variables are (unless otherwise indicated) from t-1, the year before an expert is hired.

Table 7: Quality of the match, firm sample.

Variables:	Mean Treated	Mean Controls	% Bias	% Bias reduction	t-test	p-value
Log (average wage)	5.3768	5.3755	0.5	99.0	0.07	0.94
Log (average wage growth from t-2 to t-1)	0.0446	0.0439	0.5	94.0	0.07	0.94
Number of employees	357.03	287.11	7.3	66.9	1.01	0.31
(Number of employees)^2	1800000	930000	5.2	45.9	0.80	0.43
Share of domestic experts	0.1462	0.1458	0.3	99.2	0.04	0.97
Share of domestic experts (t-2)	0.1540	0.1546	-0.4	98.8	-0.06	0.95
Share of high-skilled workers	0.3228	0.3242	-0.6	98.7	-0.10	0.92
Share of medium-skilled workers	0.3532	0.3544	-0.7	98.2	-0.12	0.91
Log (turnover)	11.9660	11.8910	4.9	90.3	0.79	0.43
Exporter (1=yes)	0.8030	0.7923	2.5	92.3	0.44	0.66
Export/turnover	0.3618	0.3581	1.1	97.4	0.17	0.87

Note: The standardized bias for a given variable is defined as the difference in means between the treated firms and the matched comparison group scaled by the average variances. The explanatory variables are (unless otherwise indicated) from t-1, the year before an expert is hired.

Table 8: Treatment effects, firm sample.

	ATET	t-stat.
Log (average wage in t)	0.0018	0.27
Log (average wage in $t+1$)	0.0111	1.81
Log (average wage in $t+2$)	0.0242	3.41
Log (employment in t)	0.0112	0.66
Log (employment in $t+1$)	-0.0133	-0.64
Log (employment in $t+2$)	-0.0327	-1.26
Log (turnover in t)	0.0128	0.64
Log (turnover in $t+1$)	0.0078	0.25
Log (turnover in $t+2$)	0.0086	0.23
Share of low-skilled workers in t	-0.0016	-0.59
Share of low-skilled workers in $t+1$	0.0002	0.05
Share of low-skilled workers in $t+2$	-0.0005	-0.11
Share of medium-skilled workers in t	-0.0021	-0.83
Share of medium-skilled workers in $t+1$	-0.0099	-2.80
Share of medium-skilled workers in $t+2$	-0.0096	-2.25
Share of high-skilled workers in t	0.0037	1.35
Share of high-skilled workers in $t+1$	0.0076	2.15
Share of high-skilled workers in $t+2$	0.0075	1.74

Note: All treatment effects are calculated using local-linear matching without replacement. The dependent variables are measured as the difference in outcome between t-1 (the year before treatment) and t or $t+1$ or $t+2$ (as indicated). A common support restriction has been imposed.

Table 9: Treatment effects, worker sample.

	All workers		Low-skilled		Medium-skilled		High-skilled	
	ATET	t-stat.	ATET	t-stat.	ATET	t-stat.	ATET	t-stat.
Log (wage in *t*)	0.0022	2.86	-0.0014	-1.09	0.0023	2.06	0.0057	3.62
Log (wage in *t+1*)	0.0008	0.96	-0.0001	-0.04	-0.0030	-2.51	0.0051	2.90
Log (wage in *t+2*)	0.0033	3.28	0.0029	1.50	0.0016	1.15	0.0065	3.04

Note: All treatment effects are calculated using nearest-neighbour matching without replacement. The dependent variables are measures as the difference in outcome between *t*-1 (the year before treatment) and *t* or *t*+1 or *t*+2 (as indicated). A common support restriction has been imposed.

Table 10: Export treatment effects, firm sample.

	ATET	t-stat.
Exporter (1=yes) in t	0.0273	2.56
Exporter (1=yes) in t+1	0.0130	0.94
Exporter (1=yes) in t+2	0.0184	1.20
Export/turnover in t	0.0126	2.42
Export/turnover in t+1	0.0148	2.09
Export/turnover in t+2	0.0163	2.06

Note: All treatment effects are calculated using local-linear matching without replacement. The dependent variables are measured as the difference in outcome between t-1 (the year before treatment) and t or t+1 or t+2 (as indicated). A common support restriction has been imposed.

Figure 1: Foreign experts in private firms

■ Manufacturing   ■ Service