Decomposing productivity differential among groups of firms: a novel inequality decomposition

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Abstract: Using the idea of the multidimensional generalization of the Duncans’ index (Silber 1992), the productivity per worker differentials across groups of firms can be decomposed into different components attributed to differences in: sectoral productivity, investment in human and physical capital, size and other determinants. More specifically, for decomposing group productivity differentials we propose an Oaxaca’s decomposition – based approach which assumes a Reimer’s weighting scheme. An application of the decomposing method aimed at evaluating productivity differences across foreign owned and domestic firms in the Italian manufacturing sector is also provided.

Keywords: Productivity, Foreign acquisitions, Oaxaca decomposition

1 Introduction

The increase of labor productivity is the driving force of improving living standards. In order to identify the sources of productivity growth, various kinds of decomposition methods are used to study the role of input reallocation induced by inter-industry and intra-industry restructuring. Decomposition methods are also used to identify sources of productivity growth even at a deeper level (firm/establishment), examining the role of intra-firm/intra-establishment restructuring as source of heterogeneity for productivity levels and growth rates between firms/establishments. Changes in the employment structures affect the skill composition, which in turn, according to the human capital literature, should be reflected in productivity and wage growth at different levels of aggregation (Maliranta and Ilmakunnas, 2005, and the relevant literature cited there).

The recent empirical literature on productivity measurement and economic growth shown evidence of the influence of firms heterogeneity on productivity differentials at both macro and micro economic level (Van Ark, 2004). Sources of productivity differentials are, even within the same industry, size, wage and skill gaps also connected to the differences in physical and human capital intensity, and differences related to competition and international trade.

In order to study the sources of labour productivity differentials between groups of firms we propose a decomposition approach for the productivity per worker differential across groups of firms into three components: one which is linked to the differences across groups in the industrial composition, one related to differences across groups in the characteristics of the firms (human and physical capital endowments, and other characteristics), and one due to differences across groups in the impacts of these characteristics on productivity (the coefficients).

The proposed method combine two different decomposition approach used in different fields of application: a number index decomposition with a regression type decomposition. Using the idea of the multidimensional generalization of the Duncans’ index (Silber 1992), and an Oaxaca’s decomposition-based approach which assumes a Reimer’s weighting scheme we propose a decomposition method able to separate the contribution of the different industrial distribution across groups from that of differences in other characteristics.

The general Oaxaca’s decomposition approach has been modified to suite the multiplicative model implied by the productivity differential
(relative aggregate productivity levels) and the productivity measure (firms’ value added per worker), and in order to separate the contribution of the industrial composition from that of differences in other characteristics. The decomposition is based on the joint generalized estimation of two labour productivity equations having correlated errors, aimed at identifying the potential determinants of value added per worker differentials and analyzing the relative importance (weight) of each source of productivity differential among the groups of firms we are interested in.

Our approach provides a way to measure the contribution of each well-identified source of productivity differential either in a micro or macro framework. However, the approach is of more general interest because it is applicable to any statistical comparison of the relative performance of two groups or a single group at two points in time. The presented approach is essentially descriptive and measure how much of the observed productivity gap is due to well identified sources of inequalities between the two groups of firms, basing on estimated associations between productivity and several factors.

We apply the decomposition to the analysis of labour productivity gap between foreign-owned and domestic firms in the Italian manufacturing sector.

Foreign-owned firms differ from domestic firms in many ways: foreign affiliates tend to be larger, employ a large fraction of skilled workers, have higher productivity levels, and capital and export intensity. Moreover, there is a concentration of foreign affiliates in R&D intensive, science-based, and scale-intensive industries (Oulton, 1998a, 1998b; Doms and Jensen, 1998; Bellak, 2004). Hence a large part of the differences in productivity between foreign affiliates and domestic firms may be due to a compositional effect, that is connected to the high concentration of foreign affiliates in specific industries and to the presence of a size factor. Davies and Lyons (1991) found that the productivity gap in the UK manufacturing sector is due for the 40% to the differential industry composition between foreign owned and domestic firms (the “structural effect”). Oulton (1998a; 1998b) found that the productivity gap is for the large part explained by the fact that foreign-owned firms have higher capital intensity and use more skilled labor than their domestic counterparts, both in manufacturing and service sectors in the UK. Griffith (1999) and Girma et al. (2001), using panel data, point out that the same factors, i.e. size, skill and capital intensity, explain great proportion of productivity differential. However, when controlling for industry and firm’s characteristics and when using more appropriate data and analysis the evidence on the productivity advantage of foreign owned firms is mixed (for a review see Bellak, 2004 and Karpaty, 2007).

2 Methodology

Our first task is to decompose the productivity per worker differential across groups of firms into different components attributed to differences in (observed) occupational structures by sector, and some potential sources of the log per worker differential. An Oaxaca’s decomposition - based approach which assumes a Reimer’s weighting scheme is used to measure and decompose the difference among the average per worker value added of the two groups of firms into three components. One is related to differences across groups in the characteristics of the firms (human and physical capital endowments, and other characteristics), a second is due to differences across groups in the impacts of these characteristics on productivity (the coefficients), and a third is linked to the differences across groups in the industrial composition.

There are alternative decomposition approaches essentially based on index number decomposition, analysis of variance, and shift-share analysis (Davis and Lyons, 1991; Duro and Esteban, 1998, Bernardini Papalia and Bertarelli, 2009; de Boer, 2008), or multiple regression of productivity by ownership. Each
method is based on the specific measure of the effects introduced into the decomposition as well as on the choice of additive or multiplicative components and on the appropriate base/comparison group. In addition when adequate data are available it also possible to directly estimate the impact on productivity due to a foreign acquisition of a domestic firm as proposed by Karpaty (2007) using a combination of propensity score matching and difference-in-difference estimators.

If compared to the other approaches, the methodology developed in this paper is of some interest since can be applied to analyze productivity differences along more than two groups or more than two dimension. It does not impose any restrictions on what productivity measures can be used and it allows for different (labour) productivity model specifications across groups.

Following the approach of Silber (1992), a multidimensional generalization of the Duncans’ index, which amounts to comparing actual with expected shares, may be derived as follows.

Let \( N_{ij} \) be the number of workers in sector \( i \) belonging to the firm group \( j \) and let \( \ln y_{ij} \) be the corresponding average logarithm of their per worker value added (VA).

The average \( \ln y_{0j} \) for all sectors belonging to the group \( j \) may be written as:

\[
\ln y_{0j} = \sum_i \left( \frac{N_{ij}}{N_{0j}} \right) \ln y_{ij}
\]

(1)

where \( N_{0j} = \sum_i N_{ij} \) is the total number of workers of group \( j \).

The average \( \ln y_{0h} \) for all sectors belonging to the group \( h \), is defined analogously.

When there is independence, the expected number of workers in sector \( i \) belonging to group \( j \), \( E(N_{ij}) \), is equal to:

\[
E(N_{ij}) = \frac{N_{0j} N_{ij}}{N}
\]

(2)

The expected gap between logs of the per worker VA relative to firms belonging to the groups \( j \) and \( h \), \( E(\Delta_{jh}) \), is equal to:

\[
E(\Delta_{jh}) = \sum_i \left( \frac{N_{ij}}{N} \right) (\ln y_{ij} - \ln y_{ih})
\]

(4)

Using Eq. (1) the actual gap between the logs of per worker VA, \( (\Delta_{jh}) \) can be written as:

\[
\Delta_{jh} = \sum_i \left[ \left( \frac{N_{ij}}{N_{0j}} \right) \ln y_{ij} - \left( \frac{N_{0j}}{N} \right) \ln y_{ih} \right]
\]

(5)

Combining Equations (4) and (5) gives:

\[
\Delta_{jh} = \sum_i \left[ \left( \frac{N_{ij}}{N_{0j}} \right) \ln y_{ij} - \left( \frac{N_{0j}}{N} \right) \ln y_{ih} \right] + \left[ \sum_i \left( \frac{N_{ij}}{N} \right) \ln y_{ij} - \ln y_{ih} \right]
\]

(6)

The expression within curly brackets in (6) represents the part of the actual per worker VA gap which is due to occupational composition by sector differences. The second part of (6) is used to compute the contribution to the gap due to some specific components such as human and physical capital, which are relevant in explaining the actual per worker VA gap \( \Delta_{jh} \).
In this respect, for each group \( j \) and \( h \), we introduce the following statistical models:

\[
\ln y_{ijl} = \sum_k \beta_{ijk} x_{ijk} + \epsilon_{ijl} \\
\ln y_{ihl} = \sum_k \beta_{ihk} x_{ihk} + \epsilon_{ihl}
\]  

(7)

where the dependent variables are the log of per worker VA of firm \( l \) operating in sector \( i \) belonging to group \( j \), \( h \). \( \beta_{ijk} \) and \( \beta_{ihk} \) are the parameters of the \( k \)-th \( (k = 1, \ldots, p) \) explanatory variables relative to sector \( i \) and groups \( j \) and \( h \) respectively. \( \epsilon_{ijl} \) and \( \epsilon_{ihl} \) are the corresponding error terms.

The regression analysis may be carried out fitting separate regression to each group or introducing a seemingly unrelated regressions (SUR) model as presented by Zellner (1962). The latter approach yields estimators at least asymptotically more efficient than single-equation least squares. This efficiency gain occurs when contemporaneous disturbance terms in different equations are correlated and when different sets of independent variables appear in the equations of the system.

Using coefficients estimates \( \hat{\beta}_{ijk} \) and \( \hat{\beta}_{ihk} \) we have:

\[
\ln y_j = \sum_k \hat{\beta}_{ijk} \bar{x}_{jk} \\
\ln y_h = \sum_k \hat{\beta}_{ihk} \bar{x}_{ihk}
\]  

(8)

Finally, applying Oaxaca’s (1973) approach to (2) and using Reimer’s (1983) weighting scheme it can be shown that the differential of the logs of the per worker VA of groups \( j \) and \( h \) of firms operating in sector \( i \) is given by:

\[
\ln y_{ij} - \ln y_{ih} = H_i + D_i 
\]  

(9)

where:

\[
H_i = \sum_k \left( \left( \hat{\beta}_{ijk} + \hat{\beta}_{ihk} \right) / 2 \right) (\bar{x}_{jk} - \bar{x}_{ihk}) 
\]  

(10)

\[
D_i = \sum_k \left( \left( \bar{x}_{yk} + \bar{x}_{uk} \right) / 2 \right) (\hat{\beta}_{ijk} - \hat{\beta}_{ihk})
\]  

(11)

\( H_i \) in Eq. (9) represents that part of the differential between the means of the logs of the per worker VA of group \( j \) and \( h \) in sector \( i \), which is explained by group differences in factor endowments relative to the determinants introduced into the model specification whereas \( D_i \) in Eq. (9) represents the contribution of group differences in the impacts of factors.

Combining Eq. (6), (9), (10) and (11) gives:

\[
\Delta_{jh} = S + H + D
\]  

(12)

where:

\[
S = \sum_i \left[ \left( \frac{N_{ij}}{N_{0j}} \right) - \left( \frac{N_{ih}}{N_{0h}} \right) \right] \ln y_j + \left[ \left( \frac{N_{ij}}{N_{0j}} \right) - \left( \frac{N_{ih}}{N_{0h}} \right) \right] \ln y_h
\]  

(13)

\[
H = \sum_i \left( \frac{N_{j0}}{N} \right) H_i
\]  

(14)

\[
D = \sum_i \left( \frac{N_{i0}}{N} \right) D_i
\]  

(15)

\( S \) in Eq. (12) and (13) represents that part of the overall differential between groups \( j \) and \( h \) which stems from the existence of group differences in occupational composition by sector. \( H \) in Eq. (12) and (14) and \( D \) in Eq. (12) and (15) give respectively the contributions of

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\(^1\) Assuming exogeneity of regressors, the conditional expectations of the error terms are zero.
group differences in factor endowments and in the impacts of factor. This decomposition separates total productivity differential between two groups of firms into three broad components: the overall endowment component given by $H$, the overall impact component given by $D$, and the $S$ component which measures the contribution of the occupational composition by sector.

Although the generalization of the Duncan index is used, the dependence between the occupational composition and the groups examined may be checked on the basis of other indices, such as entropy indices or generalizations of the Gini index. However, the present study is limited to the use of the generalization of the Duncan index which also refers to the case when more than two groups are distinguished, but this does not imply that this index should be preferred.

3 Concluding Remarks

In this paper we propose an approach to decompose productivity differentials among groups of firms. The idea is to decompose the productivity gap among groups of firms into three different components that can be interpreted as the part of the gap that is explained by group differences in: (i) average observable characteristics of the firms, (ii) the impact of these characteristics, and (iii) workforce composition by sector. The methodology developed in this paper does not impose any restrictions on the choice of the productivity measures and on the specification of the productivity model of each group of firms. The proposed approach is used to explain differences in productivity between foreign owned and domestic firms in the Italian manufacturing sector.

This particular decomposition is interesting because it quantify the extent to which the aggregate productivity advantage is due to different industrial distribution (the structural effect) and to different characteristics (inputs endowment and other factors), and how much it reflects a tendency of foreign-owned firms to be more productive than their domestic-owned firms counterparts within each industry.

Our results, based on data from a survey carried out by Capitalia for the years 2001-2003, show that productivity differential between foreign-owned and domestic firms is due to the different sectoral workforce composition only for the 10% of the total differential but a large part (ranging from 28% to 43%) is due to the different performances of firms in the two groups. Differences in characteristics between firms in the two groups accounts the more for the 62% of the overall productivity differential but its weigh falls to the 47% when characteristics other than input factors are considered.

Davies and Lyons (1991) propose an approach based on a number index decomposition for the manufacturing sector in the UK that distinguish between two components: a “structural effect” that measure the extent to which the aggregate productivity advantage is due to a better industrial distribution in the group of foreign owned firms and a “ownership effect” that reflects the tendency for foreign-owned enterprises to be more productive than the domestic-owned counterparts. However the ownership effect that result from their decomposition “may be due to pure efficiency and technology differential, but... it might equally be due to differential in labour skills, capital input, vertical integration or monopoly power in the product market” (Davies and Lyons, 1991). Our decomposition method goes furthers and allows to disentangle the effect due to differences in the impacts of factors (characteristics’ coefficients) from the effect due to differences in factors’ endowments (characteristics).

It is applicable to any statistical comparison of the relative performance of two groups or alternatively of a single group at two points in time even when the analysis is focused on productivity differences along more than two groups or more than two dimension.

This method should be of interest also in the decomposition of price and poverty indices by population subgroups as well as in the growth
model analysis aimed at decomposing the total output into factor contributions and a residual term that is the total factor productivity.

References